MILITARY MEDICAL MANUALS

GENERAL EDITORS:
SIR ALFRED KEOGH, G.C.B., M.D., F.R.C.P.
LT.-GEN. T. H. J. C. GOODWIN, C.B., C.M.G., D.S.O.

DISABILITIES OF THE LOCOMOTOR APPARATUS

AUG. BROCA
EDITED BY
SIR ROBERT JONES

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DISABILITIES OF THE LOCOMOTOR APPARATUS, THE RESULT OF WAR WOUNDS

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DISABILITIES OF THE LOCOMOTOR APPARATUS THE RESULT OF WAR WOUNDS

BY

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GENERAL INTRODUCTION

The infinite variety of injuries which any war presents to the surgeon gives to military surgery a special interest and importance. The special interest and importance, in a surgical sense, of the great European War lies not so much in the fact that examples of every form of gross lesion of organs and limbs have been seen, for if we read the older writers we find little in the moderns that is new in this respect but is to be found in the enormous mass of clinical material which has been presented to us and in the production of evidence sufficient to eliminate sources of error in determining important conclusions. For the first time also in any campaign the labours of the surgeon and the physician have had the aid of the bacteriologist, the pathologist, the physiologist, and indeed of every form of scientific assistance, in the solution of their respective problems. The clinician entered upon the great war armed with all the resources which the advances of fifty years had made available. If the surgical problems of modern war can be said not to differ sensibly from the campaigns of the past, the form in which they have been presented is certainly as different as are the methods of their solution. The achievements in the field of discovery of the chemist, the physicist and the biologist have given the military surgeon an advantage in diagnosis and treatment which was denied to his predecessors, and we are able to measure the effects of these advantages when we come to appraise the results which have been attained.

But although we may admit the general truth of these statements, it would be wrong to assume that modern scientific knowledge was, on the outbreak of the war, immediately useful to those to whom the wounded were to be confided. Fixed principles existed in all the sciences auxiliary to the work of the surgeon, but our scientific resources were not immediately available at the outset of the great campaign; scientific work bearing on wound problems had not been arranged in a manner adapted to the requirements—indeed, the requirements were not fully foreseen; the workers in the various fields were isolated, or isolated themselves, pursuing new researches rather than concentrating their powerful forces upon the one great quest.

However brilliant the triumphs of surgery may be—and that they have been of surpassing splendour no one will be found to deny—experiences of the war have already produced a mass of facts sufficient to suggest the complete remodelling of our methods of education and research.

The series of manuals, which it is my pleasant duty to introduce to English readers, consists of translations of the principal volumes of the "Horizon" Collection, which has been appropriately named after the uniform of the French soldier.

The authors, who are all well-known specialists in the subjects which they represent, have given a concise but eminently readable account of the recent acquisitions to the medicine and surgery of war which had hitherto been disseminated in periodical literature.

No higher praise can be given to the Editors than to say that the clearness of exposition characteristic of the French original has not been lost in the rendering into English.

MEDICAL SERIES

The medical volumes which have been translated for this series may be divided into two main groups, the first dealing with certain epidemic diseases, including syphilis, which are most liable to attack soldiers, and the second with various aspects of the neurology of war. The last word on *Typhoid Fever*, hitherto "the greatest scourge of armies in time of war," as it has been truly called, will be found in the monograph by MM. Vincent and Muratet, which contains a full account of recent progress in bacteriology and epidemiology as well as the clinical features of typhoid and paratyphoid fevers. The writers combat a belief in the comparatively harmless nature of paratyphoid and state that in the present war hæmorrhage and perforation have been as frequent in paratyphoid, as in typhoid fever. In their chapter on diagnosis they show that the serum test is of no value in the case of those who have undergone anti-typhoid or anti-paratyphoid vaccination, and that precise information can be gained by blood cultures only. The relative advantages of a restricted and liberal diet are discussed in the chapter on treatment, which also contains a description of serum-therapy and vaccine-therapy and the general management of the patient.

Considerable space is devoted to the important question of the carrier of infection. A special chapter is devoted to the prophylaxis of typhoid fever in the army. The work concludes with a chapter on preventive inoculation, in which its value is conclusively proved by the statistics of all countries in which it has been employed.

MM. Vincent and Muratet have also contributed to the series a work on *Dysentery, Cholera and Typhus* which will be of special interest to those whose duties take them to the Eastern Mediterranean or Mesopotamia. The carrier problem in relation to dysentery and cholera is fully discussed, and special stress is laid on the epidemiological importance of mild or abortive cases of these two diseases.

In their monograph on *The Abnormal Forms of Tetanus*, MM. Courtois-Suffit and Giroux treat of those varieties of the disease in which the spasm is confined to a limited group of muscles, *e.g.* those of the head, or one or more limbs, or of the abdominothoracic muscles. The constitutional symptoms are less severe than in the generalized form of the disease, and the prognosis is more favourable.

The volume by Dr G. Thibierge on *Syphilis in the Army* is intended as a *vade mecum* for medical officers in the army.

Turning now to the works of neurological interest, we have two volumes dealing with lesions of the peripheral nerves by Mme. Athanassio-Benisty, who has been for several years assistant to Professor Pierre Marie at La Salpêtrière. The first volume contains an account of the anatomy and physiology of the peripheral nerves, together with the symptomatology of their lesions. The second volume is devoted to the prognosis and treatment of nerve lesions.

The monograph of MM. Babinski and Froment on *Hysteria or Pithiatism and Nervous Disorders of a Reflex Character* next claims attention. In the first part the old conception of hysteria, especially as it was built up by Charcot, is set forth, and is followed by a description of the modern conception of hysteria due to Babinski, who has suggested the substitution of the term "Pithiatism," *i.e.* a state curable by persuasion, for the old name hysteria. The second part deals with nervous disorders of a reflex character, consisting of contractures or paralysis following traumatism, which are frequently found in the neurology of war, and a variety of minor symptoms, such as muscular atrophy, exaggeration of the tendon reflexes, vasomotor, thermal and secretory changes, etc. An important section discusses the future of such men, especially as regards their disposal by medical boards.

An instructive companion volume to the above is to be found in the monograph of MM. Roussy and Lhermitte, which embodies a description of the psychoneuroses met with in war, starting with elementary motor disorders and concluding with the most complex represented by pure psychoses.

SURGICAL SERIES

When the present war began, surgeons, under the influence of the immortal work of Lister, had for more than a quarter of a century concerned themselves almost exclusively with elaborations of technique designed to shorten the time occupied in or to improve the results obtained by the many complex operations that the genius of Lister had rendered possible. The good behaviour of the wound was taken for granted whenever it was made, as it nearly always was, through unbroken skin, and hence the study of the treatment of wounds had become largely restricted to the study of the aseptic variety. Septic wounds were rarely seen, and antiseptic surgery had been almost forgotten. Very few of those who were called upon to treat the wounded in the early autumn of 1914 were familiar with the treatment of grossly septic compound fractures and wounded joints, and none had any wide experience. To these men the conditions of the wounds came as a sinister and disheartening revelation. They were suddenly confronted with a state of affairs, as far as the physical conditions in the wounds were concerned, for which it was necessary to go back a hundred years or more to find a parallel.

Hence the early period of the war was one of earnest search after the correct principles that should be applied to the removal of the unusual difficulties with which surgeons and physicians were faced. It was necessary to discover where and why the treatment that sufficed for affections among the civil population failed when it was applied to military casualties, and then to originate adequate measures for the relief of the latter. For many reasons this was a slow and laborious process, in spite of the multitude of workers and the wealth of scientific resources at their disposal. The ruthlessness of war must necessarily hamper the work of the medical scientist in almost every direction except in that of providing him with an abundance of material upon which to work. It limits the opportunity for deliberate critical observation and comparison that is so essential to the formation of an accurate estimation of values ; it often compels work to be done under such high pressure and such unfavourable conditions that it becomes of little value for educative purposes. In all the armies, and on all the fronts, the pressure caused by the unprecedented number of casualties has necessitated rapid evacuation from the front along lines of communication, often of enormous length, and this means the transfer of cases through many hands, with its consequent division of responsibility, loss of continuity of treatment, and absence of prolonged observation by any one individual.

In addition to all this, it must be remembered that in this war the early conditions at the front were so uncertain that it was impossible to establish there the completely equipped scientific institutions for the treatment of the wounded that are now available under more assured circumstances, and that progress was thereby much hampered until definitive treatment could be undertaken at the early stage that is now possible.

But order has been steadily evolved out of chaos, and many things are now being done at the front that would have been deemed impossible not many months ago. As general principles of treatment are established it is found practicable to give effect to them to their full logical extent, and though there are still many obscure points to be elucidated and many methods in use that still call for improvements, it is now safe to say that the position of the art of military medicine and surgery stands upon a sound foundation, and that its future may be regarded with confidence and sanguine expectation.

The views of great authorities who derive their knowledge from extensive first-hand practical experience gained in the field cannot fail to serve as a most valuable asset to the less experienced, and must do much to enable them to derive the utmost value from the experience which will, in time, be theirs. The series covers the whole field of war surgery and medicine, and its predominating note is the exhaustive, practical and up-to-date manner in which it is handled. It is marked throughout not only by a wealth of detail, but by clearness of view and logical sequence of thought. Its study will convince the reader that, great as have been the advances in all departments in the services during this war, the progress made in the medical branch may fairly challenge comparison with that in any other, and that not the least among the services rendered by our great ally, France, to the common cause is this brilliant contribution to our professional knowledge.

A glance at the list of surgical works in the series will show how completely the ground has been covered. Appropriately enough, the series opens with the volume on *The Treatment of Infected Wounds*, by A. Carrel and G. Dehelly. This is a direct product of the war which, in the opinion of many, bids fair to become epoch-making in the treatment of septic wounds. It is peculiar to the war and derived directly from it, and the work upon which it is based is as fine an example of correlated work on the part of the chemist, the bacteriologist and the clinician as could well be wished for. This volume will show many for the first time what a precise and scientific method the " Carrel treatment " really is.

The two volumes by Professor Leriche on *Fractures* contain the practical application of the views of the great Lyons school of surgeons with regard to the treatment of injuries of bones and joints. Supported as they are by an appeal to an abundant clinical experience, they cannot fail to interest English surgeons, and to prove of the greatest value. It is only necessary to say the *Wounds of the Abdomen* are dealt with by Dr Abadie, *Wounds of the Vessels* by Professor Sencert, *Wounds of the Skull* *and Brain* by MM. Chatelin and De Martel, and *Localisation and Extraction of Projectiles* by Professor Ombrédanne and R. Ledoux-Lebard, to prove that the subjects have been allotted to very able and experienced exponents.

ALFRED KEOGH.

PREFACE

INVOLVED in the success of the "Collection Horizon," my little work on *The After Effects of Wounds of the Bones and Joints* is, along with others of this series, already out of print. A "second edition, revised and considerably augmented," represents an amount of work and labour that I have always found most tedious and irksome, and that I believe is often of but very little value to the reader. Hence I have preferred to write a new book altogether, taking for my subject, not as formerly traumatic osteomyelitis, but what was in the former book the subject of secondary importance, viz. the study of the mechanical disabilities of the locomotor apparatus. A long attendance at the Grand Palais has convinced me that such disabilities, often quite easy to prevent, to improve, and even to cure completely by one who has but a slight knowledge of orthopædic surgery, are only too often neglected and allowed to develop and to pass from bad to worse. A very frequent result of this is that the patient, astonished when informed that a further operation is necessary, refuses to give his consent, almost invariably alleging as his reason either :

1. "I have already been in hospital so many months and have suffered quite enough"; or

2. "I have been under treatment now for so many months, and no one has ever before proposed that."

Indeed, the surgeon is fortunate if the patient does not add that he has been advised on no account to submit to such an operation.

Under the circumstances, then, it seems to me to be necessary to insist further on certain definite principles of orthopædic surgery, to describe the principal operations that become necessary, their indications, and the results that are to be expected from them. I believe that most of the mistakes which have been made, and the apparent neglect that has ensued, have been the result largely of ignorance, the attention of the profession having been during the last thirty years too much focussed on abdominal surgery. The war, alas, has shown that surgery of the limbs has also its *raison d'être*, and that a sound knowledge of the principles of orthopædic surgery is indispensable for its successful practice. Before the war there existed a tendency to regard those that made a specialty of this branch of surgery as rather superior sorts of bone-setters. During the next twenty years, perhaps, some attention will be paid to their experience. In the meantime many surgeons are too busy re-discovering for themselves principles that have long been classic in orthopædic practice; or in abusing, by wholesale application, certain valuable orthopædic procedures—valuable, really, only in certain definite circumstances, and then only when used with knowledge and discretion. Such a re-discovery of the classic traditions of orthopædic surgery would be irritating had not Ecclesiastes taught us that "There is no remembrance of former things; neither shall there be any remembrance of things that are to come with those that shall come after."

PREFACE BY ENGLISH EDITOR

To the surgeon this war has brought many difficult problems which require solution. The first of these, and the most startling, was the problem of the cure, or, if possible, of the prevention of the virulent sepsis with which almost all of these war wounds were at first affected. This aspect of the war wound has now lost most of its tragedy, so that wounds which previously were in the majority of cases fatal are now treated much in the same way as similar cases in civilian life.

With the disappearance of this more acute problem of sepsis, however, another equally important one stands out in greater relief. This is the problem of the prevention and of the cure of deformity, which is almost always preventable, and attention to which does not in any way interfere with the treatment of the septic infection, but rather assists such treatment.

As the author has so well said, the fundamental principles of the treatment of these bone, joint, and muscle injuries are old, and are chiefly the application of mechanical principles to the prevention of probable mechanical deformities. In no place, perhaps, can this be better seen than in the case of a gunshot wound of the shoulder in which the joint has been destroyed.

If an ankylosis is allowed to occur with the arm closely adducted to the side in the usual position, the functional result can never be anything but poor, whatever the after-treatment; but if the ankylosis has occurred with the arm abducted and slightly in front of the coronal plane, then the muscles controlling the scapula will act on the arm, so that the loss of movement in the shoulder joint will be so well compensated for that only close examination will show the presence of deformity.

In this book the author lays down clearly and concisely both the deformity which may follow any particular injury and the method by which that deformity may be partially or completely prevented.

It is extremely valuable to the operating surgeon in many ways, as it allows him to realise what the after-results of many of his surgical procedures really are, and not what he hopes they will be. This is specially noticeable in the discussion on excision of elbows, where we see that, in the author's opinion, the end results of excisions, carried out by a great number of different surgeons both as early and late procedures, do not justify this operation as a routine procedure when compared with the excellent functional result obtained from an ankylosis in good position.

The author has put forward a strong argument for the standardised terminology of the measurement of flexion and extension of any joint, and he has laid down a basis of measurement which will enable us easily and immediately to understand the exact position of a joint from the mere statement of the number of degrees of flexion and extension in which the joint was placed.

As in every other line of work, skill in the choice of the particular form of treatment which should be applied to any particular case does not come easily or at once, but a careful adherence to the principles enunciated here will enable the surgeon to treat these difficult and frequently disheartening cases on the right lines, and so steer between the two sources of failure—namely, excessive zeal and obstructive temerity.

Points of difference must needs arise in surgical procedure between various schools and nations. In the orthopædic centres established in this country tendon transplantation has, contrary to the author's opinion, proved of great value. More especially is this the case when irreparable damage has been inflicted upon the musculo-spiral nerve, and we find further that tendon fixation has a recognised place in the foot-drop of sciatic palsy. The distinguished position which the author occupies commands for him a respectful hearing on the subjects upon which he writes.

ROBERT JONES.

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A JOINT may become affected as regards the stability, the strength, and the range of its movements by lesions that involve

1. the joint itself—its bony or ligamentous elements ;

2. the surrounding soft parts, which include :

(*a*) The skin and subcutaneous connective tissue, cicatricial retraction of which often succeeds in putting a definite obstacle in the way of joint movement in one or more directions.

(*b*) The muscles, which, with their tendons, become atrophied, fibrotic and retracted, shortened, adherent or paralysed.

3. The shafts of neighbouring bones which, after fracture, have either united in mal-position or else failed to unite altogether.

Such lesions end in a great variety of mechanical disabilities—unstable or flail joints, muscular weakness or absolute loss of power, deformities and attitudes that in themselves are disabilities, ankylosis and stiffness of joints ! To give a description of all the possible combinations of these conditions would be quite impossible, so great is their variety, owing to the nature and complexity of the initial destruction of tissue, and on the severity and character of the infective complications. There exist, however, certain clinical types which will be studied in this book in the order already laid down.

In addition, in the most complex cases, an accurate comprehension of the exact nature of the original lesion is an indispensable condition for adequate and rational treatment, and for determining which cases are amenable to physiotherapy, and which require operative surgical interference. The classification of cases into these two classes—those in which physiotherapeutic and those in which operative measures are indicated—has not up to the present always been carried out with sufficient accuracy, so that it is not at all rare to meet with cases that have stagnated for long periods in physiotherapeutic centres, receiving treatment that is useless or inadequate; either hopelessly inadequate, as in persistent attempts to mobilise a joint the seat of complete ankylosis, whether bony or firm fibrous; or useless, as when progress beyond a certain point becomes impossible because of the existence of a mechanical obstacle that can be overcome only by its surgical removal. There is another class of case which I need not at present do more than refer to, but in which treatment by such physiotherapeutic methods is absolutely harmful and pernicious.

On the other hand, it is not always easy to determine at what moment or by what method an operation should be performed, nor can its probable degree of success be foretold with anything like absolute certainty. The surgeon may be convinced of the existence of a definite mechanical obstacle to movement, but, uncertain of the possible co-existence of other lesions, he cannot be sure that its removal alone will result in restoration of the desired range of movement.

Let no one expect, then, to find in this book any absolute data concerning pathological anatomy, classification, or operative technique, but merely certain constant fundamental principles in connection with the best methods for the reduction of disability.

PART I

ARTICULAR LESIONS: ANKYLOSIS

THE VARIETIES OF ANKYLOSIS

All lesions that end either in limitation or in complete suppression of the normal range of movement of a joint are usually included in the one general term of ankylosis.

To be correctly used, however, this term should be held strictly to imply the complete cessation or disappearance of the initial causative pathological process in the joint. Now, very often the full significance of this element in ankylosis is not grasped. How often, for instance, does one hear described as ankylosis the limitation of joint movement that characterises the earlier stages of a tuberculous arthritis ? By constituting a serious error in nomenclature this often leads to a consequent grave mistake in treatment ; for so long as inflammation, whatever its origin and nature, is still present in a joint, it is that inflammation against which all treatment should be concentrated ; and such treatment is in most cases, if not in all, the exact opposite of that indicated in the condition of ankylosis of the joint in which the inflammation has finally subsided.

Ankylosis, thus defined, includes a great variety of conditions that it is very difficult if not impossible to classify with any exactness in definite water-tight compartments.

According to the pathogeny and the nature of the lesions concerned and the degree of the functional disability that results from them, we can and should distinguish, however, between the following varieties of ankylosis :

Intra- and Extra-articular Ankylosis,
Fibrous and Bony Ankylosis,
Complete and Incomplete Ankylosis.

But these different categories overlap ; for example, fibrous intra-articular ankylosis is often practically a complete ankylosis, falls in effect into the same clinical category as complete bony anyklosis ; certain cases of extra-articular ankylosis will prove to be bony and complete ; others of incomplete bony ankylosis will be found to result from overgrowth or deformity of the articular ends of the bone ; certain cases of manifestly intra-articular origin will be clinically cases of mere stiffness of peri-articular origin.

In practice, however, and as far as surgical indications are concerned, two principal forms of ankylosis are to be recognised :

1. True ankylosis, most often of intra-articular origin, in which all attempts at treatment by non-surgical means are doomed to failure.

2. Joint stiffness or false ankylosis, in which, on the other hand, mobility is to be restored in the first place by physiotherapeutic methods, assisted in different cases to a greater or less degree by occasional surgical intervention.

In cases of complete ankylosis the position of fixation of the joint is of capital importance ; in cases of incomplete ankylosis and of mere joint stiffness,—the direction and the range of the movement that remains. These determine to a great extent the future utility of the limb. I will discuss these points in connection with true ankylosis in the case of each of the individual joints.

CHAPTER I

TRUE AND COMPLETE ANKYLOSIS

1. General Considerations

Nomenclature.—True ankylosis is that in which all movement, active and passive alike, is suppressed, and in which a restoration of mobility cannot be effected except by the performance of a definite surgical operation—that of joint resection ; of the indications for this operation as of those for the correction of a concomitant mal-position a careful consideration is necessary.

Almost always such ankylosis is of an arthritic, of a definitely inflammatory origin ; in war surgery it usually follows a suppurative arthritis that has been complicated and accompanied by a more or less chronic inflammation of the neighbouring articular bone. Such a process almost inevitably ends sooner or later in bony ankylosis ; sometimes, however, in very firm fibrous intra-articular ankylosis—a condition to all practical intents and purposes identical with that of actual synostosis.

In the same practical class with these forms of intra-articular ankylosis is to be placed that variety of ankylosis in which are formed peri-articular bridges of bony outgrowths that arise by ossification of the muscles and tendons. In such also it will at once be evident that the operative removal of these exostoses offers the only chance either of correction of the fixed mal-position or of the successful mobilisation of the joint.

Because of a tendency to recurrence after removal of these exostoses the treatment of this condition, *ankylose cerclée*,—a variety of ankylosis that most commonly affects the elbow joint—often presents considerable difficulties. I have never met with this condition in war wounds, but both in order to avoid the necessity for referring to it later on, and because its study leads to important practical considerations, I will devote a little space to it here.

As a matter of fact it is one of the possible consequences of backward dislocation of the elbow joint in young people, and indeed, in my experience, the younger the patient the more marked the condition. In the first place, massage favours the formation of the osteophytes; secondly, where actual ossification of the periosteum and of the muscles has occurred, massage has the effect of stimulating and not of checking the process; in the third place, a too early removal of the bony outgrowths is very apt to be followed by their recurrence; only one operation should be performed, and that only when the new bone has become dense and compact. I will say no more about this condition, because I have met with no example of it at the Grand Palais, where, however, I have seen several cases of stiffness following dislocation of the shoulder, but none after dislocation of the elbow joint.

Certain cases of incomplete ankylosis, in which the range of movement is merely limited in one or more directions, are to be regarded as cases of true ankylosis when the cause of such limitation is bony, either intra-articular (from inflammatory overgrowth of an infected articular epiphysis) or extra-articular (for example, the projection forwards of a buttress of the upper fragment of a supracondylar fracture of the humerus). In these cases, after care has been taken to ascertain the possible existence of any additional cause of stiffness of the joint, it will be necessary, according to the circumstances of the case, either to remove surgically such a bony obstacle or to leave it alone, and it is the duty of the clinical observer to consider and decide which of these alternatives should be adopted in individual cases.

In order to establish the existence and the nature of such obstacles to full joint movement as exist a radiographic plate should always be taken; merely screening the part does not allow of a sufficiently detailed examination.

In this way one is enabled to see whether or not the joint space between the articular surfaces is clear or opaque. Opacity indicates the existence of a synostosis. Two plates taken at right angles to each other will show whether such a synostosis is complete or partial, and, in the latter case, its exact position and extent. On the other hand, transparency of this joint line does not in a case of ankylosis necessarily mean that this is fibrous and not bony, since we know that newly-formed bone may remain for long permeable to the X-rays. The radiograms will also show quite clearly any peri-articular deposits or spurs of bone, any changes in the size and shape of the epiphyses, and also the existence and position of patches of inflammatory rarefaction.

Information gained thus by radiographic examination is not always absolutely definite and decisive, but it is very much more so than that gained by simple clinical testing of the existence—under an anæsthetic where necessary—of residual movement in the joint, or by noting, in an unanæsthetised patient, the presence and amount of the pain induced by attempting to mobilise the joint.

A combination of these methods is, however, useful in coming to a decision as to the indications for treatment that exist in individual cases.

Indications for Treatment.—In all cases of true ankylosis the important question to decide is whether operation is indicated or not. In coming to a decision on this point, whilst regarding the position of ankylosis as the most important factor, we have also to take into consideration the nature, the extent, and the seat of the pathological basis of the limitation of the joint movement. There will be, for instance, less hesitation in removing a mere bony outgrowth than in practising a free full resection of the affected joint.

The position of ankylosis will remain, however, by far the most important consideration. In the case of each joint there exist positions of ankylosis that interfere but little with the functional utility of the limb, others that seriously diminish, even in some cases almost completely abolish, such utility. These various positions will be discussed a few pages further on in connection with each of the individual joints.

Hence the indications for treatment may be summed up in the following manner :

1. In cases of ankylosis in good position we have to consider whether operation furnishes a fair chance of

restoring the mobility of the joint; where it does not, it is definitely contra-indicated.

2. In cases of ankylosis in mal-position the fundamental indication is the correction of the mal-position, its conversion into a position that is from the functional point of view more useful; the possibility of in addition restoring the joint mobility must be regarded as a secondary consideration.

Cases of incomplete ankylosis in which the range of movement that persists does not allow of the joint assuming its position of maximum utility are to be regarded as cases of ankylosis in mal-position; for example, incomplete ankylosis of the knee joint with extension limited to 135° and with a normal range of flexion carries with it the same mechanical consequences as would result from complete ankylosis of the joint at this angle of 135°. Again, an incomplete ankylosis of the knee joint in which full extension but only a few degrees of flexion is possible is from this point of view practically identical with complete ankylosis in full extension.

It is most necessary to adhere to a constant fixed system of expression of these measurements of joint angles; such is in practice very rarely carried out. Thus one very commonly hears such an expression as "ankylosis of the elbow joint at 135° of flexion," *i.e.* at an obtuse angle; what is really meant is ankylosis at 135° of extension; and when it is said that flexion of the elbow reaches 45°, what is meant is that 45° of flexion beyond the right angle is possible; in other words, that there is present 135° of flexion. For hinge joints, like the elbow and the knee, the only scientific method of estimating the degrees of flexion and extension consists in regarding the 0° of one movement as the maximum of 180° of the movement in the opposite direction. An elbow in the straight or fully extended position of the arm should be regarded as possessing 0° of flexion or 180° of extension, and these two opposite movements should be estimated in correspondingly opposite directions. Thus 45° of flexion should be synonymous with 135° of extension. As regards the common expression "ankylosis of the knee or elbow in the semi-flexed position," this really implies that the vertical, fully extended position is taken as the point of departure, and the right angle as the point of arrival or termination of the movement, so that this expression is synonymous with 45° of flexion or with 135° of extension. In point of fact, it is the right-angled position that in the case of hinge joints should be regarded as the point of semi-flexion or of semi-extension.

In the case of joints where circumduction is possible, one should always take the vertical position of the particular bony lever that is regarded for the moment as the active moving one (the subject occupying the traditional anatomical position) as the point of departure, the 0° of the scale for all the movements. It is very often held that the hip joint is in the extended position when the thigh is vertical, and that any further movement backwards of the thigh constitutes hyperextension: this again is a further example of inaccurate terminology, for the vertical position should always be regarded as the point of departure, the 0° of the scale from which is to be estimated the number of degrees alike of flexion and extension as of abduction and adduction; in the case of these two last movements this is indeed the mode of measurement usually adopted.

In the same way, this vertical axis should be taken as the 0° of the scale in the measurement of rotation of joints, movement inwards and outwards around this being measured in the case of the joints of the limbs, movement to the right and to the left in the case of the joints that occupy the sagittal plane (joints of the head and spine).

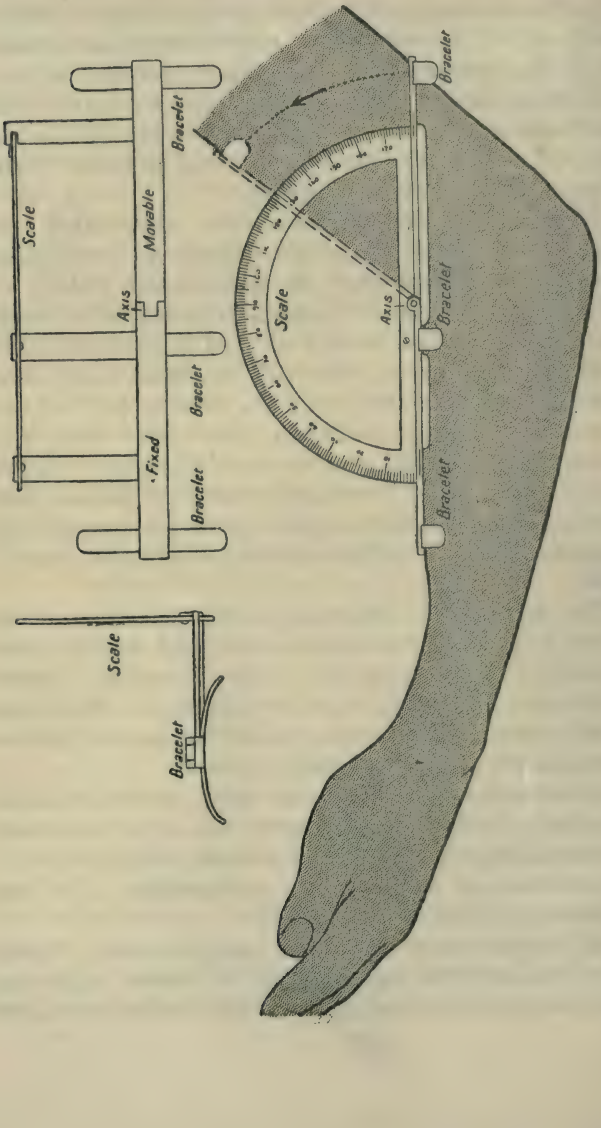
The very simple goniometer represented on page 18 is that used by Dr Schaer in the physiotherapeutic department at the Grand Palais, of which he is in charge. It consists merely of a simple metal hinge, to the far end of each lever of which is attached a bracelet that half encircles the corresponding segment of the limb. Projecting out on one side of these levers are three cross-bars, two below and one above the level of the hinge. To the two first is fixed a semicircular scale subdivided into 180°; the third abuts against this scale, and thus indicates the size of the angle at which the joint is fixed.

The axis of the hinge is placed opposite the line of the joint, the two bracelets are fixed on the corresponding segments of the limb respectively above and below the joint, and the reading on the scale gives accurately and at a glance the range of movement, active or passive, that is present.

Operative Procedures.—Having thus outlined the indications for treatment, let us see what operative methods are at our disposal for their fulfilment.

1. *Cases of ankylosis in mal-position.*—For the correction of this we can

(*a*) have recourse to forcible manipulation. This is effective, however, only in cases of fibrous ankylosis, and in many of these the possibility of its perform-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ance becomes obvious only at the last moment, when the patient is under the anæsthetic and everything is ready for an open operation.

(*b*) remove by open operation the cause of the ankylosis. This consists either of the resection of a limited osseous outgrowth, as in cases of extra-articular bony ankylosis or *ankylose cerclée*, or in the case of true intra-articular synostosis, of a full typical resection of the joint itself.

(*c*) divide either by osteotomy or by osteoclasis one of the bony levers of the joint, and by subsequent manipulation of the limb below the seat of this fracture place it in the desired position.

2. *Cases of ankylosis in good position.*—In these cases the question has to be decided whether it is better to be content and leave the joint ankylosed, or to attempt by surgical intervention restoration of the joint mobility.

In the lower limb, where considerations of stability, of support of the body weight, are all-important, the general rule should be to be content, to refrain from interference in cases of ankylosis in good position; even indeed in cases of ankylosis in mal-position in which we are forced to operate, we should deliberately aim at the production of a true bony ankylosis in the corrected position.

In the upper limb the problem is not so simple; it is complicated by rather different conditions, since here mobility is at least as important as stability. In cases of ankylosis in bad position, correction of this by resection of the joint gives at the same time an opportunity of attempting to regain a part at least of the former range of movement; where restoration of mobility is deliberately aimed at, as in cases of ankylosis in good position, resection of the joint will become necessary.

It is in connection with the elbow joint and the shoulder joint that the functional results of ankylosis in good position and those of late secondary resection of the joint for the sole purpose of restoring mobility have to be compared ; in this connection, however, no general rules can be here laid down.

I will only point out the necessity for the exercise of caution in the performance of open operations, or even of subcutaneous osteoclasis or manipulations that involve tissues formerly the seat of a suppurative osteomyelitis. We learned the necessity of this long ago in connection with the spontaneous osteomyelitis of adolescence ; and we have found out that the infection of war wounds survives in a latent form the healing of the wound over even longer periods. We have, then, constantly to beware of recrudescence of the infection, so that in doubtful cases of ankylosis in which the functional utility is fair we should incline towards abstention from active intervention ; in any case we should always postpone as long as possible any operation considered advisable or necessary, for time is the chief agent in the complete sterilisation of these healed foci of osteomyelitis.

In order to institute a useful comparison between the functional results of ankylosis and those of resection of the same joint it is necessary to pick out cases of the former condition as of the latter in which the musculature and the remaining joints of the limb are in good functional condition. In the case of the elbow joint it is the state of the hand and of the wrist that from this point of view, and as regards the future usefulness of the limb, is all-important; moreover, this depends very much less on the operative methods that have been adopted, on whether resection has been performed or not, than on the involvement either in the original trauma or in the subsequent infection of vessels, muscles, and nerves, and also in cases in which such early lesions have been practically identical, on the attention that has been bestowed on the rest of the limb during the period of healing of the wounds. It would be unfair to compare in the upper limb a resection that has been skilfully performed but of which the after-treatment has been neglected, the remaining joints of the limb having been allowed to remain immobile and grow stiff in a sling, with a case of ankylosis in good functional position, in which, however, due attention has been given to the full use of the other joints of the limb, and notably to those of the hand; and the converse is equally true. In connection with disabilities in the hand, in cases of resection of the elbow joint, I often wonder whether in many more cases than is usually thought the surgeon is not responsible for the lesion of certain of the nerve trunks that lie in close relation to this joint, especially of the ulnar nerve. Of course one will say that such a thing never occurs at the hands of any surgeon worthy of the name; the fact remains that occasionally it does occur even with most skilful and experienced operators, and nowadays all who operate cannot be so described. I will compare, then, the cases of ankylosis that I have seen with cases of primary resection at the front and with cases of secondary resection for acute suppurative arthritis, even although it is not always easy to ascertain to which of these categories a case belongs. We shall see that in general the functional result of such resections is far from ideal. Not in the least does this mean that such operations are to be condemned on principle ; it is meant only as a warning concerning the common defects presented by such cases ; it should always be remembered that these resections have saved the patients' lives, have been performed strictly as an alternative to amputations, and as such have been of signal service to the patients, have been the means of preserving the use of a hand that at the best is perfect, at the worst of fair utility, and of an elbow that, supported by a light apparatus with lateral hinge joints, is infinitely more useful than the best artificial arm. At the worst in these cases the surgeon has ample time in which to decide on late amputation should the limb thus preserved prove to be less useful than a good artificial arm.

But I am encroaching on the study of individual cases. I will now pass on to consider these in detail.

2. Ankylosis of the Fingers and Toes

(*a*) *The Fingers.*—Whether the affected joint be the metacarpo-phalangeal or an inter-phalangeal, the occurrence of ankylosis with lateral deviation of the finger distal to the lesion is in most cases quite incompatible with the carrying on of a manual trade, and the only rational treatment consists in amputation ; this should be so planned as to conserve as great a length of stump as possible and as is compatible with a good covering for the bone end and a good position of the scar. A palmar scar should always be avoided, as should also a terminal scar in cases where, as in inter-phalangeal amputations and in ex-articulation of the metacarpo-phalangeal joint of the thumb and of the index finger, the end of the stump must be prepared to bear a certain amount of pressure. In planning the flaps, whilst it is necessary to pay particular attention to the position and extent of the scar of the initial wound, yet one should adhere as closely as possible to the classical operative text-book directions (palmar flap with dorsal scar for amputations through the phalanges of the fingers and thumb, simple dorsal racquet incisions for ex-articulation of the metacarpo-phalangeal joints of the middle and ring fingers, excentric palmar flaps for ex-articulation of these joints of the index and little fingers). In cases where after primary incomplete amputations a tender adherent terminal scar exists, one is often forced to shorten the stump in order to get a good covering for the end of the bone and a satisfactory position for the scar.

In cases in which no lateral deviation of the finger exists, ankylosis in flexion will almost always be found to be most disabling, and this in an increasing degree the nearer the ankylosed joint lies to the root of the finger ; there is, for instance, but little disability in such ankylosis in flexion of the terminal phalanx, but it becomes considerable in the case of the middle phalanx, serious where the metacarpo-phalangeal joint is the seat of the ankylosis. Wherever this deformity interferes with the working use of the hand, the only reasonable treatment consists in amputation through the ankylosed joint. Osteotomy followed by fixation in extension is not to be recommended, for ankylosis of either of the two proximal phalanges in extension is in the case of a manual worker quite as great a disability as their permanent flexion. We need not consider the terminal phalanx, for the loss of it is quite negligible. In other words, a finger that remains stiff and projects out during flexion of the others simply catches on everything and gets in the way.

Besides, in the case of war wounds ankylosis of a finger joint is usually complicated by the presence of adherent scars, and by such loss or adhesion of tendons as serves to render ordinary conservative methods quite impracticable.

In cases too where a finger remains stiff and useless simply from division of its tendons, amputation is indicated whenever tendon suture is obviously out of the question or has failed. Where, however, passive flexion or extension of the finger is possible, the patient often learns to get the finger—immobile though not necessarily stiff—to follow the movements of its neighbours; although, even in such cases, occasionally the hand worker finds that he is better off without the finger.

In war surgery as in industrial accidents it is common to meet with cases of multiple lesions of the hand—ankylosis, peri-articular stiffness, partial or complete amputation, tender and disabling palmar scars occurring together in different fingers of the same hand.

No precise general rules can be laid down for the treatment of such cases; it can merely be said that during the period of healing one should adopt as conservative an attitude as possible, and that when healing has occurred everything should be done to retain or regain the power of opposition of the thumb so that the patient is able to pick things up; by excision and plastic operation to get rid of disabling scars; to improve the general condition of the finger stumps; and to remodel a useful finger out of the scarred and tense mass of skin that is binding together two fingers into one, etc.

In the case of the thumb, conservative measures should be pushed to their extreme limit.

(*b*) *The Toes.*—A stiff toe that projects "out of the ranks" in any direction, whether flexed, extended, or overlapping its fellows either above or below, interferes with the wearing of the boot, and should be amputated. Even simple permanent flexion of a terminal joint constitutes a serious disability.

Hallux valgus should be treated by such a resection of the head of the first metatarsal bone as does not interfere with its important function of transmission of such part of the weight of the body as passes through the antero-internal part of the foot. I believe, however, that the walking disability resulting from amputation of the great toe with part or the whole of its metatarsal bone has been greatly exaggerated; on the other hand, I have seen patients in whom the adoption of conservative methods has resulted in ankylosis with an upward and inward projection of a great toe, the removal of which with the anterior part of its metatarsal bone should long before have been carried out.

If but one or two toes remain unamputated it is better to remove them also, for as long as the scar is situated well on the dorsum of the foot, amputation of all five toes gives an excellent functional result.

3. Ankylosis of the Wrist Joint

(*a*) *The position of election for ankylosis.*—There exists a considerable difference of opinion as regards the relative functional utility of ankylosis at about 45° of extension and ankylosis in the straight line.

The arguments put forward in favour of the extended position are, that it has been shown by the use of Marey's tambour that with the hand in this position a better and stronger grip is obtained on an object or implement, and that it is in this position of the wrist that almost all manual labourers perform their work. But in ordinary life this is an inconvenient position; that of ankylosis in the straight line is better suited to the essential requirements of everyday life. For choice, however, one may allow 15° to 20° of extension.

(*b*) The natural or instinctive position assumed by the wrist and hand in a patient suffering from inflammation of this joint is that of flexion, and unless precautions be taken to prevent it, this is the position in which ankylosis will take place. Such is the almost inevitable result of suspending the arm on the chest in a sling.

(*c*) During treatment this is the position against the adoption of which it is necessary to guard by splinting all cases in which, because of the presence of suppuration or the disposition of the wounds, the application of a plaster is out of the question. As soon as such becomes practicable, however, some means has to be devised, in the first place, of getting the forearm into supination, in the second, of slightly extending the wrist joint. Where necessary, this may be done under an anæsthetic. Further on (*vide* page 89 and following) I will deal with the necessity for the earliest possible mobilisation and use of the fingers.

Cases of ankylosis in flexion with preservation of active movement of the fingers should be treated by resection of the joint; long ago Ollier demonstrated that in this way free movement at the wrist joint can be obtained. Personally, however, I have not met with any case of this sort; ankylosis in flexion—a condition the careful surgeon will almost always succeed in avoiding—is practically always the result of neglect, and under these circumstances a concomitant stiffness of the fingers will have inevitably occurred, thereby rendering the performance of such an operation quite useless.

Immobilisation of the wrist joint in flexion is, however, sometimes unavoidable; for example, in order to maintain the reduction of the fragments in certain simple fractures of the radius. Such should always be of very short duration, and corrected, under chloroform if necessary, as early as possible.

4. Ankylosis of the Forearm

In other words, loss or limitation of the movements of pronation and supination.

(*a*) *The position of election for ankylosis* in cases where all movement is suppressed is that of semipronation; full pronation and full supination are alike positions of considerably greater functional disability.

Where the ankylosis is incomplete, the position is to be regarded as favourable when, whatever the amount or direction of the movement (pronation or supination), this position of semi-pronation can at any rate be reached.

(*b*) *The position instinctively assumed*, whether the bones are fractured or not, is, when the patient lies recumbent with his arm by his side, that of full pronation ; that of semi-pronation where, the patient recumbent or erect, the elbow is flexed to a right angle and the forearm is supported across the chest in a sling. Unless precautions to the contrary be taken, union in this latter position of the lower fragments is likely to take place in fractures, simple or compound, of the bones of the forearm, and especially in fractures of the radius.

The position of election in which the forearm should be maintained during treatment will depend then altogether on whether return of movement is to be expected or not.

In cases of suppurative arthritis of the elbow joint, in which ankylosis, complete or almost so, is certain to occur, the forearm should be fixed in semi-pronation. On the other hand, in cases of fracture it should be immobilised as early as possible in the position of full supination. In these cases of fracture a return of at least a great part of the range of movement is to be expected. If this position of supination be not assured, if the case be left more or less to itself, the lower fragments of the fractured bones will assume a position of partial pronation in relation to the supinated upper fragments, and, although the actual process of union may proceed satisfactorily, a form of mal-union will result, the lower fragments remaining permanently pronated ; in this way a permanent loss or impairment of the power of supination of the hand, active and passive, is brought about. Such condition only too often results from the frequent immobilisation in semi-pronation of such fractures in plaster—a permanent persistence of the semi-pronated position and a corresponding permanent limitation of the range of supination.

For other reasons also this position of supination is desirable: in it the two bones of the forearm remain parallel and do not cross; and in addition it is in this position that the width of the interosseous space is greatest. Apart from the form of mal-union or *décalage* just described, the chief cause of disability to be guarded against in fractures of these bones consists in an excessive formation of callus that, encroaching more or less on the interosseous space, limits sometimes to almost complete suppression the movements of pronation and supination; or else the occurrence of a complete synostosis between the two bones, resulting again of course in complete loss of all such movement.

Radiographic examination alone is capable of accurately diagnosing such lesions; surgical intervention alone can cure them. This should consist of:

1. Simple osteotomy with subsequent immobilisation in full supination in cases where union of the lower fragments has taken place in pronation.

2. The removal of such excess of callus as by encroaching on the interosseous space is interfering with the range of movement.

3. In cases of synostosis, resection of the bridge of bone uniting the radius and the ulna.

The indications for the performance of each of the three of these operations should be regarded not as absolute but as relative to the degree of the mal-union and to the extent of the professional disability.

5. Ankylosis of the Elbow Joint

(*a*) *The position of election for ankylosis* of this joint has been much debated. With some surgeons it is the right angle, or even a slightly acute angle, with the forearm in semi-pronation ; with others it is an obtuse angle somewhere between 125° and 135° of extension, the forearm being fully pronated.

The former have in their minds the performance of the necessary common acts of everyday life, such as eating, dressing, etc. ; the latter are almost wholly preoccupied by considerations connected with the patient's occupation, for example, of the force necessary in the use of a plane or of a file ; and the position of ankylosis that they recommend is really that adopted by most manual labourers in their daily work.

Any position between 135° of extension and the straight line is incontestably bad ; the limb remains practically useless even in cases of incomplete ankylosis in which there exists some range of movement within these limits.

(*b*) *The instinctive position of rest* being that of 135° of extension, a difficult question to decide is whether in the course of an inflammation of the elbow joint one should respect this naturally assumed position or interfere with it and insist on fixing the joint instead at a right angle.

Ankylosis in complete extension will always be avoided by a careful surgeon ; at a favourable moment during the healing of the wound he will take steps to correct such a position.

From my personal observation of cases of actual ankylosis of the elbow joint, most patients seem to be better served by the right-angled position ; in time it seems to become better adapted to the conditions of their work than the obtuse angle ever becomes to the performance of the essential acts of everyday life. Hence I am accustomed to fix in this right-angled position all elbows likely to become ankylosed, irrespective of what the special occupation of the patient may be. As, moreover, in most cases free use of the limb is allowed before complete consolidation of the synostosis has taken place, the mere weight of the limb may usually be relied on to open out the angle of the elbow a few degrees in the direction of extension, so that in this way one has always to count on a probable future loss of these few degrees of flexion.

In some cases the occurrence of incomplete ankylosis is to be anticipated; for example, in cases of supracondylar fractures of the humerus with forward displacement of the upper fragment. In such the excess of callus that is formed will only too effectively interfere with the subsequent attainment of full flexion of the elbow. In this condition, then, the limb should be immobilised, with the elbow joint acutely flexed, for this is the position most likely to maintain the reduction of the fragments; besides, in such cases it is always more difficult to regain the full range of flexion—certainly the more useful of the two movements—than it is the full range of extension. In the restoration of this latter range, moreover, the weight of the forearm and hand can always be counted on as assisting.

(*c*) The operative methods at our disposal for the *redressement* of an elbow joint ankylosed in malposition are two: (*a*) forcible correction by manipulation; (*b*) resection of the joint. Corrective osteotomy is never indicated.

(*a*) Forcible mechanical mobilisation, introduced in the pre-antiseptic days, is now no longer used. Correction by manipulation is nowadays confined to certain cases of firm fibrous ankylosis. Up to a certain point radiography can furnish some indication of the possibility or the probability of its performance; but in many cases a final decision can be arrived at only at the last moment, when with the patient under the anæsthetic the persistence of a small amount of movement is detected. Hence in some cases although preparations will have been made for the performance of a full resection of the joint this will be proved to be unnecessary, correction by forcible manipulation being found possible. Where a considerable amount of peri-articular induration with an extensive adherent posterior scar exists, this forcible *redressement* may result in extensive laceration of the cicatricial tissue, a laceration that may even involve the partially obliterated joint cavity. This happened to me in a case of ankylosis of the elbow in full extension in which the condition of the hand was excellent. Healing of the wound proceeded slowly but smoothly, and a useful arm, ankylosed at a right angle, resulted.

(*b*) Joint resection, when performed with the limited object of an improvement in the position of the ankylosis, consists really of a cuneiform osteotomy of the synostosis. This removal of bone, whilst being as economical as possible, should always be carried out strictly sub-periosteally, so as to retain at the seat of the resection a maximum of osteogenetic tissue. I will discuss later the question,—in what class of case is one justified in aiming at restoration of mobility in performing a resection that is really an arthroplasty.

The indications for the performance of *redressement* of ankylosed elbows may be gathered from what I have already said; consequently they become absolute only in cases in which the position of ankylosis exceeds 135° of extension. In all other cases the wishes of the patient and the nature of his work should be taken into account. I will add that whilst I have never been asked by a patient to alter the right-angled position, I have several times been requested to convert an obtuse angle into a right angle.

Cases of incomplete ankylosis with retention of movement between 135° of extension and full extension should be treated as cases of complete ankylosis in a position anywhere between these two points; where, however, there exists movement between 135° and 90° of extension, operation is not indicated except in such cases—which, however, are not met with in war surgery—of limitation of flexion by the forward projection of a buttress of the upper fragment of a supracondylar fracture; such a cause of limitation of joint movement is easily removed without actually opening the joint itself.

(*d*) *Resections that aim at restoration of mobility.*—When performed in a certain definite manner, resection of the elbow joint may be followed by a return of mobility, by the formation of a pseudo-arthrosis or ne-arthrosis—a fact known long enough ago, for remarkable examples are to be found cited in Ollier's immortal work, *Traité des Resections*. In my opinion it would be decidedly wrong because of the occurrence of such cases to make a regular practice of this operation, whether performed early to obviate ankylosis, or late after ankylosis has become an accomplished fact.

I have seen at the Grand Palais, both in the physiotherapeutic department and in the depôt for the supply of surgical appliances, a considerable number of early primary resections of the elbow joint. Where the original destruction of tissue had not been great and the nerves of the limb had escaped, where the operation had been well performed and the after-treatment adequately carried out, the result was in some cases good in the sense that the movement of the fingers and of the wrist were intact and strong, active flexion of the elbow was stable, and the condition of the shoulder excellent.

The whole point seems to consist in operating before the muscles have had time to waste and undergo degeneration, and also in the institution of muscle training and treatment at the earliest possible moment after the operation. It is also, however, of great importance that the surgeon should have been trained in the practice of bone surgery in order that a strictly sub-periosteal removal of the fragments and regularisation of the bony ends by means of the saw should be carried out. It should not be forgotten, moreover, that all surgeons do not possess this qualification; again, it is inevitable in war conditions that those who at the front perform the operation are unable themselves to take charge of the after-treatment, since evacuation before healing is complete is unavoidable. Hence the frequency of cases that fall considerably short of the standard that I have described, cases in which the function of the hand is but fair and active flexion of the elbow remains weak or is absent altogether.

Even if, however, I restrict examination to cases that on the whole show a good result, those, for example, that have been exhibited at the Société de Chirurgie by surgeons who regularly and systematically perform this operation, and have hence a large experience of it, the fact remains that I have so far seen no case in which a certain amount of lateral mobility was not present, or in which the power of active extension of the joint had been retained. Almost all were in effect "flail elbows," in which, although in many active flexion was good and strong, yet extension was merely passive, so that whenever the extended arm was raised beyond the horizontal the action of the triceps was insufficient to hold the joint in extension against the action of gravity, and so the forearm immediately and passively dropped again into the flexed position.

Hence in the majority of the patients who were manual workers an appliance with lateral steel supports and hinges, and even in some cases with ratchets, became necessary. Experiments carried out at the Grand Palais by Nepper and Vallée with Marey's ergograph have definitely proved that the muscular strength of the arm is always greater in cases of ankylosis than in the best cases of resection.

Taking all things into consideration, many of these cases, I repeat, are nevertheless very remarkable; by an extensive removal of loose bone fragments—so extensive as to render the occurrence of ankylosis impossible—amputation of the limb has been avoided, and in addition to life, a limb remains infinitely better than an artificial arm; this is true even in cases in which, because of the extent of the initial tissue destruction or of the severity of the infective complications, but a limited amount of use remains to the hand; at the worst in such cases one can always perform amputation later should it become necessary on account of causalgic or trophic trouble.

It is not, then, fair to compare the results of these extensive early primary resections with those of secondary resection for suppurative arthritis or of late orthopædic resection in cases of ankylosis.

But already the facts appear to me to demonstrate that it would be quite wrong to systematise into a routine the performance of this operation of primary resection, to resort to it at once as a prophylaxis against suppurative osteo-arthritis and in order to avoid the muscular wasting that in the long run of such resections forms the most important element in the prognosis, or to perform it in cases of but moderately extensive shattering of the bone—cases often with but little or no infection.

I am not ignorant of the teaching of those who recommend this operation, that joint resection is the most effective method of joint drainage; I grant that it is. Can we be quite certain, however, that so drastic a method of drainage is really thus necessary in the treatment of sepsis in the case of the elbow joint? As far as preservation of life goes, I unhesitatingly affirm that it is not. I have performed secondary resection in none of my cases of elbow wounds, and all have survived with a condition of hand and shoulder that corresponded strictly with the extent and nature of the original wound; in all, it is true, there exists ankylosis at a right angle, but I consider from what I have seen of the results of resection that there is no necessity for me to repent of this.

These remarks are meant in no wise as a criticism of those surgeons at the front or at the base who perform free resection in cases of either extensive bone comminution or of severe sepsis ; there is room for a difference of opinion among surgeons of equal worth as to when the necessity for an operation has arisen. I only say that as regards myself I am not in favour of this operation, for its performance very often results in excessive mobility of the elbow, and that, in my opinion, is always functionally inferior to firm ankylosis in good position.

As regards the restoration of mobility in an elbow already ankylosed by a late resection that includes a wide sub-periosteal removal of bone, this can undoubtedly be accomplished, and the success in many cases is even remarkable ; it should not be forgotten, however, that a permanent false joint does not always result, that in some cases a recurrence of the ankylosis takes place.

One is certainly justified in attempting this, however, in the case of patients who are not going to perform hard manual work, and in whom a resection for mal-position is in any case indicated. But from what I have seen of the results of other surgeons, it would take a very special combination of circumstances to persuade me to attempt such an arthroplasty in the case of a patient with ankylosis in good position. I am not denying the occurrence of remarkably successful cases ; but I certainly insist on the necessity for the recognition of the failures, of the occurrence of cases in which the joint, in so far as the presence of lateral mobility and the absence of strong active flexion go, remains weak and flail ; of cases in which a recrudescence of the infection takes place, with the formation of abscesses among the flexor muscles of the forearm that result in their subsequent sclerosis and retraction ; of the cases that

I have seen at the Grand Palais of arms definitely crippled that before the operation were firm and strong; of the cases I have met at the Société de Chirurgie, which although there has been primary union of the operation wound, yet have seemed to me to be on the whole not better but worse off than they were before the operation. Besides, who, operating in the seat of an old war wound, can with certainty guard against a recurrence of osteomyelitis?

My views on this subject may be summed up and expressed as follows:

1. Cases of ankylosis at a right angle should never, except under very special circumstances, be subjected to operation.

2. In cases of ankylosis in a position between 135° and 180° of extension, the indications for correction should be regarded as absolute; where the position of ankylosis lies between 135° and 90° of extension, the indications for intervention should be regarded as dependent on the occupation and wishes of the patient.

3. Where the ankylosis is fibrous, the correction should whenever possible take the form of manual *redressement* and not of joint resection.

4. Whenever resection is undertaken for bony ankylosis, it should be remembered that mobility is often gained at the expense of stability.

6. Ankylosis of the Shoulder

(*a*) *The general mechanism of the shoulder movements.* —The functional value of the shoulder joint in any case may be regarded as being strictly proportional to the range of abduction present in that case; in other words, the disability consequent on disease of this joint may always be estimated by measuring the distance by which, when the patient raises his hand up to or beyond the level of his head, the arm falls short of the vertical position—the limit of the range of normal abduction.

In order fully to understand this movement of abduction of the arm it becomes necessary to study it carefully, to analyse it, and to decide what part in it is played by the scapulo-humeral or shoulder joint and what by the scapula and by the clavicular joints.

On manipulation of the shoulder joint—the scapula meanwhile being fixed by its lower angle in the vertical position in a vice—the observer will find—what indeed the extent of the cartilaginous covering of the articular surfaces of the shoulder joint would lead him to expect—that the movement of direct abduction of the arm in the frontal plane comes to an end as soon as the humerus reaches the horizontal—in adults even when it is still a few degrees short of this level. The lower axillary part of the capsule is at this moment stretched to its utmost, and effectually prevents further abduction of the arm; thus the joint has become "blocked," and as the scapula is already fixed, all further movement in this direction becomes manifestly impossible.

But in the cadaver and also in the normal living subject there is of course no such immobilisation of the scapula. This bone is normally kept in contact with the chest wall solely by muscular action, being suspended from the clavicle through the ligaments of the acromio-clavicular joint. The clavicle, abutting internally against the manubrium sterni, can normally be raised higher than the horizontal level; on the other hand, resting, as it does, on the first rib, it cannot descend below this horizontal level.

If then, having come to the point when the shoulder joint is "blocked," and at which the humerus has become horizontal, the observer now persists in the passive abduction movement of the humerus, he will find that all further abduction of the arm is accompanied by and due to a rotation of the scapula around its supero-external angle or neck, which in the meantime remains a fixed point; the acromion becomes elevated, and the clavicle slopes upwards and outwards; the long axis of the scapula, hitherto vertical, now runs obliquely downwards and outwards; its vertebral border of course shows the same obliquity, and its inferior angle, becoming slightly elevated, is at the same time displaced considerably outwards towards the axilla.

The active movement of abduction, taking place at the shoulder joint, and resulting in elevation of the arm to the horizontal, is effected by the action of the deltoid; such elevation may be pure abduction, an outward and upward movement strictly in the frontal plane, carried out by contraction of all the fibres of this fan-shaped deltoid muscle; or it may be accompanied by flexion of the shoulder joint, the result of the action of the anterior deltoid fibres assisted by the pectoralis major; or again the arm during elevation may be kept behind the frontal plane—in other words, the abduction is accompanied by extension, although the range of this combined movement is but slight—and this is effected by contraction of the posterior part of the deltoid in company with the latissimus dorsi and the teres major.

The muscle responsible for the rotation of the scapula during the second part of abduction of the arm is the serratus magnus.

In the living subject the passive movement may be investigated in the following manner: the subject sits astride a chair and displays his back to the observer, who, seizing the lower angle of the right scapula between the thumb and index finger of his left hand, with the other abducts the right arm of the subject from alongside his body. At a certain definite moment he will feel the angle of the scapula commence to slip from between his fingers in an outward direction towards the axilla. The moment of commencement of this scapular rotation marks the limit of the mobility of the head of the humerus on the glenoid cavity; in other words, the limit of abduction at the scapulo-humeral joint.

(*b*) *The movements in ankylosis of the shoulder joint.* —When the shoulder joint is either completely or incompletely ankylosed abduction of the arm takes place by scapular rotation, either wholly and from the outset in the case of complete ankylosis, or partially and after the completion of as much of the normal range of abduction as is possible at the incompletely ankylosed joint.

An examination carried out as described above is indispensable for a correct appreciation of the amount and nature of this movement in each individual case. As a matter of fact, whenever the shoulder joint is completely ankylosed a certain amount of relaxation of the ligaments of the clavicular joints gradually takes place, and this results in a compensatory increase in the range of the scapular rotation that, so long as the serratus magnus remains in strong action, goes far to diminish the amount of the functional disability from the articular lesion.

This is what takes place when the ankylosis of the joint has occurred with the arm in adduction, the vertebral border of the scapula remaining vertical whilst the arm hangs close to the side. Where, however, the ankylosis has taken place in abduction, the vertical position of the arm will be found to correspond to an inward and downward obliquity of the vertebral border of the scapula, so that the inferior angle, whilst occupying a slightly higher level, has come to lie distinctly nearer the middle line. In such a case, upon the commencement of abduction of the arm from the side the scapula is in a position of adduction; consequently, and to a corresponding extent, its range of abduction will be diminished.

Ankylosis of the shoulder in internal rotation is compensated for by carrying the point of the shoulder backwards; this gives an antero-posterior range of movement to the claviculo-scapular apparatus, whilst at the same time there is an opening out of the angle between these two bones. Ankylosis of the shoulder joint in external rotation (a much more serious disability) is compensated for by carrying the point of the shoulder forwards and rounding the back. In this way is created a postero-anterior range of movement for the clavicle and scapula; at the same time, the angle between these two bones narrows to become more acute.

I have described the scapular mechanism at length, because I wish to point out how great an importance should be attributed to the active and passive movements of the scapula in coming to a decision as to the degree of the disability that is present; and this all the more, because certain military instructions forbid its being taken into account. As a matter of fact, from the point of view of many professions and trades, ankylosis of the shoulder even when complete constitutes but a moderate disability provided that the normal movements of the scapula are intact; on the other hand, even when incomplete, it constitutes a grave infirmity when the scapula is either fixed by scars or adhesions or immobilised by paralysis or muscular weakness.

(*c*) *The position of ankylosis.*—Ankylosis almost always takes place with the arm in the vertical plane, abducted to 15 or 20 degrees, and in slight internal rotation; in other words, in an attitude in which compensation by the scapular movements remains adequate. Hence in the case of the shoulder joint there exists no antagonism between this position of election of ankylosis and the instinctive position of repose adopted by the joint during inflammation.

As soon, however, as the period of painful distension of the joint has passed, and especially when the patient commences to get about, the weight of the arm spontaneously effects the slight amount of correction that is necessary in its position, and this before the long-delayed process of consolidation of the synostosis has become complete.

As a matter of fact, I have never seen a case of ankylosis of the shoulder joint in which correction was at all necessary.

I have, however, seen—in civil work, but not in military—several cases of mal-union with angulation of the upper part of the humeral shaft, in which it became necessary to perform osteotomy followed by immobilisation in abduction, so that the long axis of the lower fragment could again come into line with that of the upper.

(*d*) I believe that the majority of surgeons do not approve of attempts to restore mobility in the case of ankylosis of the shoulder joint by the performance of an arthroplasty.

There are, it is incontestable, cases in which such resection of the shoulder joint has been followed by recovery of perfect function, with the formation of an almost perfect ne-arthrosis. For example, I have published a case of a boy who as a baby had had resection performed for osteomyelitis (a procedure, however, of which I cannot approve), and possessed at fourteen years a joint with perfect movement in every direction, and in addition a good development of the shoulder muscles.

In civil surgery this is, however, the only case of its kind that I have seen ; in war surgery, among the very numerous cases of resection that I have studied, resections that had been either primary or secondary and performed for acute suppuration, I have seen no such case.

Where the resection has not been very extensive it usually ends in ankylosis, and in this case the patient has not, in my opinion, very much to be dissatisfied about. Where, on the other hand, it has been extensive a pseudo-arthrosis nearly always results, with complete absence of all active movement of the arm on the body.

In the majority of such cases the deltoid has become atrophied or else has been in part destroyed, so that the arm hangs limp and flail in action as in repose. Where, however, the whole or a good part of this muscle has escaped the arm hangs flail in repose only, but as soon as the deltoid contracts it raises the end of the humerus against the scapula; this furnishes a point of support for the use of the elbow and hand. But in either case all active power of abduction is lost. It is not possible to supply this action by means of any external support or appliance, and these have all a disadvantage of their own in that in order to support the flail shoulder they require to embrace the elbow, and so interfere with its range of movement. Hence it becomes only too obvious that the disability in pseudo-arthrosis of the shoulder is almost always infinitely greater than that of ankylosis.

I repeat that I have seen nothing but pseudo-arthroses result from resection of the shoulder joint; moreover, I am speaking not merely of the cases that have been referred for the supply of a surgical appliance (which is rarely of much use), for it might quite well be argued that the good results having no need of such would thus be missed; I am speaking also of the cases that have come to the centres of physiotherapy for muscle training. I may also add that very few cases of an even fair result have been shown at the Société de Chirurgie, where, however, many have appeared of resection of the elbow joint (which also, in my opinion, is practically always inferior to ankylosis in good position); and if there had been many, it is reasonable to suppose that some at least would have been exhibited there.

As regards primary resection, I will repeat what I said in the case of the elbow joint; that, in my opinion, it would be wrong to adopt it as a routine measure, or to complicate its performance by very extensive removal of bone fragments; that it seems to be better to be content to lose a little time, to make sure first of ankylosis, and then to operate as economically as possible. At the same time, however, one gets the impression that a good number of these cases have by resection avoided a disarticulation through the shoulder joint, and in this case, where they possess the fair use of elbow and hand, they have much to be thankful for.

The position is the same as regards those cases of secondary suppurative osteo-arthritis which, threatening life without showing any evidence of abscess formation or of pus tracking down the arm, cannot be checked by mere arthrotomy followed later by partial successive removal of sequestra and bone fragments, with ankylosis as the end result; in these it often becomes possible to save the arm by performing resection. Now, many surgeons consider that such a course should be the rule, holding that resection alone can assure adequate drainage of a suppurating shoulder joint. In such cases it is true one can often carry out a subcapsulo-periosteal resection by simply removing with the chisel the head only of the humerus, the bone being divided at its anatomical and not at its surgical neck; but I do not think that there is much chance of this operation resulting in the formation of a stable ne-arthrosis. I believe indeed that firm ankylosis will very much more often result, but I am equally certain that such a procedure would result in the production of a good number of pseudo-arthroses with the pathological and functional features that I have just described.

Where, then, the performance of simple arthrotomy is sufficient to assure the life of the patient, I regard it as being by far the better operation, from the point of view of the future function of the limb; at any rate, all that I can say is that I have by this means succeeded in curing all the cases of suppurative arthritis of the shoulder joint that have come under my care, and that all have ended in firm ankylosis.

It is on this account that almost all surgeons refuse to countenance the treatment of ankylosis of the shoulder by the performance of an arthroplasty—an operation that is exceedingly likely to end in a flail joint, especially as in all these cases there is never much chance of recovery of power in the atrophied or partly destroyed deltoid.

In cases of extensive loss of substance of both humerus and of scapula with widespread destruction of soft parts the arm often becomes drawn upwards and inwards against the side of the body by the retraction of a wide, deep mass of scar tissue; in this way is furnished in many cases quite a good point of support for the movements of the elbow and hand. Unfortunately, however, these cases are very often complicated by lesions, primary or secondary by compression, of the axillary vessels and nerves.

Where the condition of the muscles round the shoulder remains good despite extensive loss of substance of the humerus itself the upper end of the bone may be cleared of scar, and the pectoralis major and the deltoid may be reinserted into it; these muscles will thus be given a chance to resume their function of suspension of the weight of the arm. Such an operation occasionally gives a brilliant result, although the conditions that alone allow of this success are unfortunately but rarely realised.

7. Ankylosis of the Foot

The joints of the foot are so numerous, and their function so complicated, that a very accurate knowledge of their normal anatomy and physiology is an essential preliminary to the study of the mechanical consequences of their ankylosis in good or in bad position.

Now, this is a very important subject, for ankylosis in mal-position of the joints of the foot is a very frequent cause of very serious disability—disability that the exercise of but a little care and forethought could very often have succeeded in avoiding, and that but a slight amount of intelligent surgical intervention suffices to cure.

An investigation of details is here all the more necessary, because the performance of the operation of arthrodesis—the production of an artificial ankylosis—is very often rendered necessary by conditions of the foot that we shall study later, and we cannot lay down rules as regards its technique, nor specify its indications, unless and until we establish with great care what the normal movements of the foot really are, what are the favourable and what the unfavourable positions for ankylosis, and what is the functional value of the different varieties of ankylosis of the various joints. I shall, therefore, be excused if I accord to the foot the place of honour among the organs of locomotion.

A. *The Normal Anatomy and Physiology of the Foot*

A. The Architecture of the Foot.—When the foot is viewed in profile from one or other side its posterior part will be seen to be formed by the two bones of the posterior tarsus, the astragalus superimposed on the os calcis. The anterior surfaces of these two bones will be at once seen to reach the same vertical and transverse planes, whilst behind the os calcis projects backwards beyond the astragalus for a distance corresponding to about one-third of its antero-posterior length.

Immediately in front of the os calcis lies the cuboid; anterior to the astragalus is the scaphoid, in front of which in turn lie the three cuneiform bones. These bones together form the anterior tarsus, and bear the five metatarsals, the inner three of which articulate one with each of the cuneiforms, the outer two with the cuboid.

These bones form a double antero-posterior arch, an outer resting on the os calcis and the two outer metatarsals, and an inner supported by the astragalus and the three inner metatarsals.

The line of the os calcis, which slopes upwards and outwards, is prolonged in the same direction by that of the cuboid, which, thus resting in the air, forms the keystone of the outer arch between its ascending part, the os calcis, and its descending, the two outer metatarsals.

Both ends of the external arch reach the ground. On the other hand, the posterior end of the internal arch, the astragalus, is supported not on the ground but on the os calcis. The head of the astragalus thus remains in the air above the ground internal to and above that of the os calcis, but in the same transverse plane; between it and the three inner metatarsal bones, which constitute the descending part of the arch, the keystone of the inner arch is formed by the scaphoid and the cuneiforms. The inner arch, much more hollow than the outer, forms the middle portion of the inner border of the foot, to which it gives its arch.

In this way this inner border of the skeleton of the foot rises higher from the ground than the outer; in a transverse direction the posterior ends of the metatarsal bones and the bones of the tarsus that carry them form a transverse arch that rises higher from the ground, as one passes from without inwards, from the fifth to the first metatarsal bone.

B. THE ARTICULATIONS OF THE BONES OF THE FOOT.—There exist three articulations between these groups of bones: (1) between the metatarsal bones and the bones of the anterior tarsus; (2) between the anterior tarsus and the posterior tarsus; (3) between the two bones of the posterior tarsus, the astragalus and the os calcis.

1. *The tarso-metatarsal joint of Lisfranc.*—Complicated as this joint is by the interlocking of the metatarsal and cuneiform bones—a fact of very great importance in operative surgery—it possesses but a very limited range of movement; the results of its ankylosis, of no practical importance, need not detain us. Before leaving it, however, I will describe the bony projections that mark the inner and outer ends of the line of this joint.

On the outer side the bulky tuberosity of the fifth metatarsal bone projects one finger's breadth backwards beyond the joint line. Internally and on the plantar surface the line of the joint lies 2 to 3 millimetres behind the tubercle of the first metatarsal bone.

2. *The mid-tarsal joint of Chopart and the sub-*

astragaloid joint.—Connected both anatomically and physiologically these two joints should be studied together, especially by the orthopædic surgeon, to whom they are of peculiarly great practical importance.

The os calcis is formed for about two-thirds of its length by a posterior portion that is obviously higher and wider than the anterior third; from this on its upper surface it is separated by a groove running obliquely forwards and outwards, which, moreover, is wide at its outer end, narrow at its inner. Behind and external to this groove on the upper surface lies an extensive articular facet that slopes inwards, backwards, and upwards—the upward element in this slope is often forgotten; in front and internal to the groove is another articular surface that belongs really not to the body of the os calcis at all but to an inwardly projecting shelf of bone that forms the lesser apophysis of the os calcis—the sustentaculum tali, which, as its name indicates, supports the head of the astragalus.

The anterior surface of the os calcis is transverse and consists of a facet that articulates with the cuboid; in a recess lies the anterior end of the sustentaculum tali, which terminates at a distance of about 15 millimetres from the scaphoid, to which it is united, however, by a powerful fibrous band, the "spring" ligament, the upper surface of which is coated with cartilage, and its inner edge reinforced by the sheath of the tibialis anticus. This is inserted into the infero-internal aspect of the scaphoid. The cartilaginous surface of this ligament is in direct continuity with that of the sustentaculum tali behind and with that of the scaphoid in front. Hence if the posterior part of a foot from which the astragalus has been removed be viewed from above there will be seen (1) postero-externally a cartilage-covered surface sloping obliquely downwards, (2) in front of this a roughly-marked groove of triangular shape, and (3) antero-externally another cartilage-covered surface that as regards its posterior half (the ligamentous and sustentacular surfaces) is plane and horizontal, as regards its anterior part is vertical but concave (the articular surface of the scaphoid).

The astragalus consists of a large cubical posterior part or body, its upper surface shaped like a pulley (I will return to consider this later), prolonged forwards into a neck and head, the under square surface of which continues to occupy the horizontal plane, whilst the upper slopes sharply forwards and downwards. This bone bears a general resemblance to a snail, its head projecting forwards out of its shell and to one side (the inner); there even exists a short tail—the backward projection of the os trigonum—that receives the sheath of the flexor proprius hallucis; moreover, just as a snail on the move hollows out the front part of its body, so the under surface of the neck of the astragalus between the head and the body is hollowed out into a rough groove. Behind this groove lies a cartilage-covered articular surface; in front another, which however is continuous round a right angle with that on the anterior aspect of the head.

This being so, one can easily understand how this snail with the rounded back lies on the os calcis—the body of the one bone on the body of the other to form the posterior sub-astragaloid joint, the upward slope of which should never be forgotten; the grooves on the two bones lie opposite to and face each other to form the non-articular sub-astragaloid tunnel or sinus ; the head of the astragalus lying on the articular surface of the sustentaculum tali prolonged in front by that of the "spring" ligament, with its anterior surface fitting into the articular hollow of the scaphoid, so that by its anterior and inferior surfaces it is received into a scapho-gleno-sustentacular socket.

The sub-astragaloid tunnel or sinus is occupied and occluded by the powerful interosseous ligament, which consists of two distinct bands that bind the two bones most firmly together. The outer part of this tunnel being wide is easily accessible to the knife ; the inner part, on the contrary, is narrow, and hence not nearly so accessible. It is from their outer side that these joints should always be approached by the surgeon.

Although the mid-tarsal joint of Chopart occupies a transverse plane between the bones of the anterior and posterior tarsus, *i.e.* between the astragalus and the scaphoid above and internally, between the cuboid and the os calcis below and externally, yet there exists a definite anatomical continuity between the inner astragalo-scaphoid portion of this joint and the anterior sub-astragaloid joint, the two together forming a single socket for the reception of the head of the astragalus ; it will also be readily understood that there exists an intimate mechanical connection between this composite joint and the posterior sub-astragaloid.

A direct guide to the transverse line of the mid-tarsal joint is furnished by the plantar tubercle of the scaphoid, which projects beyond this line for a distance of from 2 to 3 millimetres. This, then, gives the line of the astragalo-scaphoid joint; on the outer border of the dorsum of the foot the line of the calcaneo-cuboid joint lies in the same frontal plane, and a finger's breadth behind the tuberosity of the fifth metatarsal bone.

3. *The ankle joint.*—This joint is situated between the tibia and the fibula, which are bound together by strong ligaments to form a socket, into which fits the body of the astragalus, its upper articular surface being pulley-shaped.

This upper surface is not absolutely horizontal, but slopes slightly downwards and outwards; it is continuous over each border, with a cartilage-covered facet that articulates with the corresponding surface on the malleolus; the inner of these lies further forwards, but does not extend so far downwards as the outer, and its long axis is antero-posterior. Of course the relative shape and position of these facets correspond with the relative positions and shapes of the articular surfaces of the two malleoli, the outer of which lies on a plane more posterior but lower than that of the inner.

Without entering on a detailed account of the shape and insertions of the ligaments of the ankle joint, it should always be borne in mind that the anterior and posterior capsular ligaments are functionally negligible, that the stability of the joint depends on the lateral ligaments, each of which, fixed above to the tip of the corresponding malleolus, is formed on the same general plan, and consists of: (1) a superficial layer, trans-astragaloid, arising from the outer surface of the tip of the malleolus and inserted below into the os calcis; and (2) a second deeper layer that consists of two chief bundles, one anterior, fixed to the neck of the astragalus, the other, posterior, and very powerful, attached to the " tail " of the astragalus.

The guides to the position of the joint line are furnished by the tips and anterior margins of the two malleoli.

It is just in front of the tip of the external malleolus, on the outer side of the foot, that the joint line of the posterior sub-astragaloid joint is to be looked for.

C. THE EXAMINATION OF THE FOOT.—I have already given some account of the relationship of the various bony prominences to the position of the lines of the joints of the foot. I have still to describe how these bony points are to be identified.

The observer should sit facing the sole of the foot, the patient meanwhile reclining with the leg fully extended and horizontal, and resting on the calf. The foot should be taken between the two hands in such a way that the thumbs meet transversely across the sole just behind the heads of the metatarsal bones and each index finger lies along the corresponding border of the foot. On palpating these borders with the tip of these fingers the surgeon will at once make out the tips of the malleoli, and on the outer side the tuberosity of the base of the fifth metatarsal bone (on palpating this outer border from behind forwards the tip of the finger will hook against this important bony prominence).

Along the inner border it is not so easy to make out either the tubercle of the first metatarsal bone or that of the scaphoid. These should be sought well on their plantar aspect; the best way to localise them is to run the tip of the finger along the under surface of the shaft of the first metatarsal bone and so reach its tubercle, then over the smooth plane under surface of the first or inner cuneiform, and so on to the tubercle of the scaphoid. Absolute certainty in the localisation of these two points is of the greatest importance. Immediately behind and above the scaphoid lies the tip of the internal malleolus. In cases in which, through swelling of the tissues of the foot, such careful palpation of these two points is impossible, the tubercle of the metatarsal bone can always be found by taking the half-way point between the inner side of the point of the heel and the tip of the great toe; and where one of these points is missing, the measurement can be carried out on the other foot, and half of this measured forwards or backwards from whichever of these two points remains.

The projections formed by the tendons that surround the ankle joint are as follows:

1. Behind the external malleolus lie the two peronei tendons, that of the peroneus brevis in front hooking acutely round its point and coming to lie above, that of the peroneus longus below, a small tubercle on the outer surface of the os calcis. A longitudinal incision a few millimetres above the level of the tip of the malleolus will display without endangering the upper edge of this tendon.

2. Behind the internal malleolus lie the tendons of the tibialis posticus and of the flexor communis digitorum. Situated in front of the other, the tibial tendon winds round the tip of its malleolus in order to lie along the glenoid or internal calcaneo-navicular ligament, with which its sheath blends, and the internal lateral ligament, and so gains the tubercle of the scaphoid. The tendon of the common flexor disappears quite suddenly into the tunnel of the os calcis. As regards the tendon of the flexor proprius hallucis, which

passes behind the astragalus and under the sustentaculum tali, it does not here approach the surface, and hence cannot be palpated. It should never be forgotten that this muscle arises from the fibula, and the flexor communis digitorum from the tibia; consequently the two tendons cross in the sole of the foot. It is important to remember this in connection with disabilities of the toes following destruction of the muscular tissue of the calf.

3. Sloping obliquely forwards and inwards in front of the ankle and lying directly on the tibia is the taut tendon of the tibialis anticus, which thus reaches its insertion into the internal cuneiform bone. External to this tendon are to be found that of the extensor proprius hallucis, those of the extensor communis digitorum, and that of the peroneus tertius, in that order from within outwards. This last gains an insertion into the tuberosity of the fifth metatarsal bone. These tendons are held in place by means of an arrangement of ligamentous bands (the annular and fundiform ligaments), which are fixed to the hollow of the os calcis; when operating to display these tendons these ligaments should always be respected.

4. Behind and at a distance from the ankle joint descends the tendo Achillis separated from the edge of the malleolus on each side by a wide groove, that is always in any inflammatory condition of the foot or leg very quickly obliterated by swelling.

D. THE ACTIVE AND PASSIVE MOVEMENTS OF THE FOOT.—The nature and directions of the movements of the foot is a subject that has lent itself to philosophical discussion, and this has resulted in a great confusion of nomenclature. The simplest system to adopt is the following:

Extension, when the point of the foot is lowered with elevation of the heel from the ground—the position of equinus.

Flexion, when the point of the foot is raised with a lowering of the heel—the position of calcaneus.

Internal and external rotation, when the sole of the foot looks respectively inwards and outwards.

The terms *varus* and *valgus* should be restricted respectively to adduction and abduction of the front part of the foot.

The alternate movements of flexion and extension take place at the hinge joint of the ankle. In the adult this joint has a normal range of between about 70° and 135° of extension, the position of 70° of extension corresponding to a position in which the long axis of the foot forms an acute angle with that of the leg.

Extension is carried out by the direct and powerful pull of the gastrocnemius and of the soleus, whose common tendon, the tendo Achillis, is inserted into the posterior aspect of the short arm of the lever of the foot formed by the os calcis. These are the only muscles that get a direct attachment to the bones of the posterior tarsus. Flexion is effected by the direct action of no such individual muscle; as a matter of fact there is no great need for strong direct flexor muscles, as in walking; flexion of the ankle joint is largely a passive movement. It is carried out, however, by the tibialis anticus and the peroneus brevis when their action on the anterior tarsus is accomplished; similarly by the extensors of the toes as soon as their extending action has become complete.

The alternate movements of adduction and abduction of the front part of the foot, resulting in the positions respectively of varus and valgus, take place at the mid-tarsal and sub-astragaloid joints, which act in concert—a concert that is indeed on anatomical grounds inevitable:

1. With adduction is associated a certain degree of equinus (a lowering of the toes and of the front part of the os calcis), and in addition some internal rotation, by a tilting round its antero-posterior axis, of the os calcis, whose outer surface thus comes to look somewhat downwards as well as outwards. At the same time there takes place a certain amount of adduction of the anterior part of this bone, so that its antero-posterior axis inclines slightly inwards as well as forwards. With the foot in this adducted position the occurrence of flexion at the mid-tarsal joint would result in the formation of a typical pes cavus.

2. With abduction is associated a certain degree of calcaneus and of external rotation, with a movement of the os calcis the exact reverse of what we have just described; this results in a tendency to flattening of the antero-posterior arch of the foot.

Hence the os calcis, following the movement of the anterior tarsus, pivots round and beneath the astragalus; the interosseous ligament, connecting the two bones together, acts as a check on the rotatory movement. As we have seen, this ligament is quite taut and short at its inner end, and this serves as the fixed point around which the pivoting takes place; whilst its outer part, being longer and looser, allows free play to the rotation of the os calcis round the fixed point. This movement of the os calcis may be compared to that of a ship swinging round a fixed point between its two ends. In Farabeul's words: "The os calcis veers and pitches and—rotating round its long axis—rolls like a ship at sea."

Movement at these mid-tarsal and sub-astragaloid joints also takes place in the reverse direction; in other words, instead of the position of the front part of the foot influencing the movements of the os calcis, these can influence and change the position of the fore part of the foot; hence the tendo Achillis, besides being an extensor of the foot, is through its attachment to the os calcis an adductor of the front part of the foot.

With the foot in the varus position the scaphoid bone sinks down somewhat into the sole, so that its tubercle becomes less prominent, whilst, on the other hand, the head of the astragalus comes to project out on the dorsum of the foot. The reverse is true in the position of valgus; the head of the astragalus becomes difficult to make out on the dorsum, and the scaphoid tubercle again becomes prominent. The varus position is also associated with an increase in the width of the outer part of the articular spaces of these mid-tarsal and sub-astragaloid joints, so that in this position these joints are more accessible for the introduction of the knife from the outer side.

Contraction of the two tibial muscles is responsible for the assumption of the varus position of the foot, although the anterior has in addition a strong internal rotatory action. The direction of pull of their tendons corresponds to lines joining their points of reflexion forward from round the ankle joint and their points of insertion into the tarsus.

The muscles that pull the foot primarily and directly into valgus are the peroneus tertius and the peroneus brevis; the extensors of the toes and the peroneus longus act only secondarily and indirectly. This last muscle, the peroneus longus, exerts its chief action on the base of the first metatarsal bone; its contraction results in a lowering of the head of this bone in a sort of movement of opposition. Hence, in the sole of the foot, its tendon acts as a ligament in maintaining the concavity of the arch of the foot.

The muscles inserted into the fore part of the foot may be compared to the reins attached to the head of a horse. When all act together and with equal force, flexion of the foot results; when those on one side possess the greater force, this balance is upset, and the foot is drawn over to the corresponding side.

Rotation inwards or outwards of the whole foot *en masse* around its long axis does actually occur; but this is, as I will endeavour to explain, a merely passive movement; such rotation of the whole foot, however, constitutes an attitude of great pathological importance. Ligaments are meant to allow a certain amount of play to a joint; actual contact of the articular surfaces is effected either by an active force—the tonicity or contraction of muscles—or by a purely passive force—the body weight—not by the direct action of ligaments. If ligaments were absolutely taut, stretched to their utmost, all joint movement would be abolished. Although, then, the ankle joint possesses only the active movements of flexion and extension, and the sub-astragaloid joint only that complex gliding movement that we have just described, there does exist at both these joints a certain range of passive movement allowing of passive rotation of the whole foot inwards or outwards, the astragalus being rotated in its mortise, and the os calcis likewise turning beneath the astragalus. Such movement, however, is not really physiological, not capable of active utilisation by the living subject. If the reader attempt to perform it actively himself he will at once realise how slight and weak it is. But when passively carried out it at once becomes of wider range, and usually the younger the subject, the wider this range. The reader can prove its actual range in himself by standing first wholly on the inner border of one foot—the corresponding leg sloping downwards and outwards with the knee adducted—and then again on its whole outer border—the knee now abducted and the leg sloping downwards and inwards. In each case the weight of the body is responsible in the first place for this passive movement of rotation of the foot, and subsequently for the maintenance of this rotated position.

B. *The Action of the Foot in Standing and Walking*

(*a*) An imprint with lampblack of the sole of the normal foot shows that *during standing* weight is transmitted through the foot to the ground over a surface that includes the whole width of the heel in the posterior part of the sole, the whole length of the outer border of the sole, half the width of its middle part, and the whole width of its anterior fourth.

In points of bony support this represents the two posterior tuberosities of the os calcis, the whole length of the fifth metatarsal, and the heads of all five metatarsal bones. The chief part of the weight is, however, transmitted through the heel and through the heads of the fifth and first metatarsal bones; of these two latter points the head of the fifth transmits the greater weight in the standing position, the head of the first during walking. The external arch of the foot is the arch of passive weight bearing, whilst the function of the internal arch is related to walking.

During standing the weight of the body has a constant tendency to flatten out the arch of the foot, to drive down the keystones of the arches (the cuboid, and especially the scaphoid); such would inevitably result in a deviation of the fore part of the foot into a position of valgus. This tendency is resisted not by the ligaments—ligaments will always in time yield to a prolonged strain—but by the tonicity of certain muscles, the short plantar muscles and the long flexor tendons, which act by tending to approximate the two extremities of the arch; in addition, as we have already described, the tibiales anticus and posticus and the peroneus longus play an important part in the maintenance of the arches of the foot.

(*b*) *During walking.*—In studying the movements of the foot (and of the whole lower limb) during walking it is necessary to commence with the military position of "attention," the trunk, thighs, and legs vertical, the heels together, the feet forming an angle of 45° with each other, the knees fully extended, and the feet at right angles to the legs; of course in addition the shoes should be removed. Place yourself in this position, and suppose that you wish to set off with the left foot.

By a slight inclination of the trunk and pelvis to the right you will put a little extra weight on the right leg, which remains vertical; by simultaneous extension of the ankle and flexion of the knee you will lift the left heel off the ground until the toes, though still in contact with it, are transmitting no weight. At this moment commences the stage of purely right-sided weight-bearing; during this stage there devolves on the gluteus medius muscle the important rôle of keeping the pelvis tilted to the right, so overcoming the action of the body weight and preventing the trunk from falling to the left.

This heavily-loaded right lower limb acting as a pivot, the left leg is swung forwards by combined flexion of the hip and extension of the knee; at the same time the whole left limb is shortened by elevation of the foot into a position at right angles to the leg; whilst the pelvis is lowered and, turning a little on its pivot toward the right, is at the same time carried forwards by complete extension of the right lower limb, which for the moment comes to slope downwards and backwards. In the meantime the left heel has come into contact with the ground; at this stage the left leg slopes obliquely downwards and forwards in a direction the exact opposite of that of the right leg, so that the distance between the two feet at this stage of bilateral support of the body weight represents the length of the pace.

The left foot, at first flexed at the ankle joint with the heel alone in contact with the ground, becomes in turn extended into a position of slight equinus with the sole now flat on the ground, then flexed to the right-angled position, and finally to an acute angle. At the same time the right limb, by an active and not by a mere passive or pendulum movement, is lifted from the ground and swung forwards.

Hence in order to be correctly and normally carried out, walking demands a range of flexion of the ankle joint to a point a little less than the right angle and of extension to almost 135°, a range of from 25 to 30 degrees of flexion at the knee joint, and a range of about 25 to 30 degrees of both flexion and extension at the hip joint. Under these circumstances only will the heel first come into contact with the ground, then the whole sole, and finally the toes alone.

When, however, a boot or shoe with a heel is worn the foot is forced to assume a position of equinus whenever the sole of the boot is flat on the ground. The usual height of the heel is from 2 to 2½ centimetres; hence during the stage of bilateral body weight bearing the knee, without being actually flexed, has not the normal tendency to become hyperextended. In proportion as the height of the heel is increased the knee will during this stage become more and more flexed, the range of movement of the ankle joint will progressively diminish until a point is reached of complete suppression of all movement of the foot on the leg; this is what occurs with the fashionable shoe with the Louis XV heel, in which the foot remains in a position of fixed equinus.

C. *Ankylosis of the Ankle Joint*

1. *Ankylosis at a right angle.*—When the ankle joint is ankylosed in this position the body weight during standing is transmitted through the foot quite normally.

In walking, the normal antero-posterior roll of the foot on the ground becomes impossible; so too is the flexion of the ankle joint that normally accompanies flexion of the hip and extension of the knee during the period of swinging forward of the limb.

Hence in order to raise the foot from the ground and carry it forward it becomes necessary to exaggerate the tendency towards rotation of the pelvis on the sound limb ; this again necessitates walking with the knee fully extended, as on a peg leg.

In time this becomes a mode of progression involving but little extra fatigue, and one, moreover, that need not be at all ungraceful, especially if a certain amount of elevation of the heel of the boot on the affected side be allowed. Where ankylosis has taken place, with a slightly acute angle between the foot and the leg, *i.e.* in a position of slight flexion of the ankle joint, a considerable improvement in the powers of walking will be noticed.

This right-angled or acute-angled position of ankylosis, then, is from the functional point of view distinctly favourable.

2. *Ankylosis of the ankle joint in a position of equinus.*—Ankylosis in the equinus position is, on the other hand, distinctly unfavourable.

In standing, the weight of the body is transmitted to the ground through the metatarso-phalangeal joints which become hyper-extended, the heel remains elevated from the ground, the knee and hip flexed to compensate for the lengthening of the limb.

In walking, too, the foot cannot be lifted off the ground without an exaggeration of the normal lateral obliquity of the pelvis and of the flexion of the knee and hip joints that is proportional to the degree of the equinus.

The foot, having thus been brought forward most ungracefully, strikes the ground, not heel first but toes first.

If the toes only can be brought into contact with the ground—which is the case in severe equinus—

the flexion of the knee, and hence also of the hip, has to persist to compensate for the obvious lengthening of the limb.

Where, however, in cases of but moderate equinus, the patient does fall back on the heel, and so succeeds in getting the sole flat on the ground, flexion of the ankle joint being impossible, there results during this stage an upward and backward obliquity of the leg; this in turn implies a hyper-extension of the knee joint just at the very time when the whole weight of the body is taken on this limb alone. This in time produces a permanent stretching of the posterior ligaments of this joint, with development of genu recurvatum and lateral mobility, so that the stability of the limb becomes seriously impaired.

Such serious and disabling sequelæ will not occur, however, (1) when the equinus is compensatory to shortening of the limb, *e.g.* from fracture of the leg or thigh, and (2) when the equinus is not greater than that given to the sound foot by the ordinary thickness of the heel of the boot.

In such cases the gait becomes merely not quite so good as that obtaining in ankylosis at the right angle.

There exists, however, a definite limit beyond which further shortening is certainly not beneficial.

1. Despite the opinion of many of the so-called "orthopædists" who make surgical boots for cases of shortening from old hip disease, walking in a position of marked compensatory equinus is not to be recommended: the weight of the body is transmitted obliquely through the point of the foot, so that the toes become hyper-extended; indeed in extreme cases the weight is taken wholly by the great toe, which, compressed into the point of the boot, becomes

painful, and not infrequently develops an ingrowing toe-nail. Loss of all normal elasticity at the ankle joint adds further to the disability. In general the patient walks much better on an ordinary high boot with the sole flat, not sloping. Should the surgeon decide under these conditions to decrease the disability by operation, I am inclined to think that he would be right; but it is certainly wrong to conclude that during treatment of the fracture the foot should be allowed to become fixed in equinus.

2. In cases where there is no shortening of the limb, but where the degree of equinus is greater than that given to the other foot by the heel of an ordinary shoe, I have often been asked to prescribe a surgical boot with a raised heel. This, however, would necessitate standing and walking with an exaggerated flexion of the knee joint.

Where there exists but 1 to 2 centimetres of elevation of the heel, such a boot may quite well be given; indeed in cases where operative correction of the deformity is impossible such is really indispensable in order to avoid the development of genu recurvatum.

Any elevation of the heel greater than this is, however, bad; in such cases an operation is absolutely indicated—cuneiform tarsectomy followed by immobilisation in plaster in good position.

3. Ankylosis of the ankle joint in equino-varus is still more disabling than the former condition of ankylosis in pure equinus. In the standing position the body weight is transmitted through the anterior part of the outer border of the foot, and even in part through the anterior part of the dorsum. Hence during the weight-bearing stage of walking all stability of the limb is lacking; and where there is no

co-existent ankylosis of the mid-tarsal joint, walking simply results in a progressive exaggeration of the varus element of the deformity.

In such cases of fixed equino-varus no surgical boot or appliance can possibly be of any use; no support, whether of leather or of metal, is capable of resisting the inward twist of the foot that occurs during the period of unilateral weight support on the point of the deformed foot. Except as regards one particular, the mechanical condition is absolutely analogous to that of congenital talipes equino-varus. In the child, an adaptation that is impossible in the adult may and often does occur, resulting in a better though not in a very graceful mode of progression: the bones of the child's foot are so much more plastic, so much more easily moulded, that in time the anterior part of the foot actually comes to lie at a right angle to the posterior part, its plantar surface looking directly backwards. Under such conditions weight is transmitted through the heads of the astragalus and os calcis, and so through the dorsum of the foot, the patient walking as on two peg legs; the feet, however, still remain to a certain extent twisted inwards, so that an excessive rolling of the pelvis becomes necessary to avoid their catching on each other as the child walks. The occurrence of such a degree of adaptation at the mid-tarsal joint in the adult is quite out of the question.

In such cases the only possible treatment consists in resection of part or of the whole of the astragalus; because of the existence of the ankylosis this will not be a typical astragalectomy; it will rather be a form of cuneiform osteotomy carried out with mallet and chisel. After such an operation it is necessary to guard against the development of a secondary varus deformity ; this will occur if the os calcis slips too far forward out of the tibio-fibular socket, so that the fore part of the foot is drawn inwards. It is advisable very often to resect in addition the anterior extremity of the os calcis.

On completion of the operation the limb should be immobilised in plaster for six weeks in a position of calcaneo-valgus.

4. The instinctive attitude of relief or repose adopted in inflammatory conditions of the joints of the foot is one of equinus, very often associated with a tendency to varus. In cases of wounds of or about the ankle joint, then, the greatest care should be taken to guard against the assumption or persistence of this position.

From the very beginning the patient should not be allowed to lie on the affected side, with his whole lower limb reposing on its outer side, the knee flexed and the foot dropped into equinus. The foot should be bandaged in such a way as to incline it into a position of calcaneo-valgus, and in this position the foot should be fixed as efficiently as possible in some form of skeleton or wire splint. Later, but as soon as is compatible with the condition of the wounds, and if necessary under an anæsthetic, the foot should be fixed in plaster in this position of calcaneo-valgus.

D. *Ankylosis of the Mid-tarsal and Sub-astragaloid Joints*

1. Ankylosis of these joints in the straight position of the foot, the long axis of its anterior part a continuation of that of the posterior, and the sole of the foot in normal relation to the ground, results in no particular disability.

Under these conditions the long adductor and abductor muscles of the foot lose all such action and become merely direct flexors and extensors of the ankle joint, the normal range of movement of which is not in the least interfered with. Moreover, although during walking the occurrence of a slight amount of extension at the mid-tarsal joint during flexion of the ankle joint adds somewhat to the grace and ease of the movement, yet the absence of this is of no great practical importance.

2. The attitude instinctively adopted in osteo-arthritic lesions of this region is that of adduction and flexion—in other words, one of varus, with equinus of the front part of the foot. Especially where there has been any loss of bone substance in the neighbourhood of this joint does the tendency to this position of cavo-varus persist for many months, chiefly owing to the cicatricial retraction of the soft parts in the sole of the foot. Such a position is, of course, one of great functional disability. Hence in these cases it is of the utmost importance to see that the foot is kept firmly fixed in a position of calcaneo-valgus until such time as the synostosis has become complete and solid.

8. Ankylosis of the Knee Joint

The position of election in complete ankylosis is that of full extension.

With the knee fixed in this position there is no change in the standing attitude of the body.

The patient walks, however, as on a peg leg, lifting the limb from the ground by tilting the pelvis and swinging it forwards by a slight movement of flexion of the hip combined with rotation of the pelvis around the sound limb. In the early days of their disability the patients walk with the whole limb externally rotated. Many never succeed in correcting this; but others, thanks to the remaining elasticity of the foot and of the hip, succeed in walking with hardly a limp, and are not more easily fatigued than a normal man.

The existence of up to 3 to 4 centimetres of shortening is decidedly favourable, as it tends to diminish the necessary range of lateral oscillation of the pelvis. This is important, for I have more than once been asked by a patient to order a high boot which would be far more of a nuisance than a benefit to him.

The occurrence of such shortening is fortunately frequent, for ankylosis of the knee joint is most commonly the result either of a resection of the joint or of a fractured femur.

In order to assure this position for ankylosis it is necessary to watch all cases of suppurative arthritis of the knee joint most carefully, for the naturally and instinctively assumed position is that of about 135° of extension, whilst, since the patient tends to lie on his affected side, this is usually complicated by some outward rotation of the tibia.

It should certainly be recorded, however, that among all the numerous cases of ankylosis of this joint that I have seen none has been in a really bad functional position. A few have been flexed 10 or 15 degrees, but this does not entail any great inconvenience. Hence it is obviously unnecessary for me to waste time here discussing the methods of splinting or of immobilising the knee joint; these, it is quite evident, are sufficiently widely known already.

Whether performed primarily for extensive bony comminution, or secondarily for a badly draining suppurative arthritis, resection of the knee joint is most certainly a valuable operation; in practically all cases it results in ankylosis of the leg in a straight line. Even in cases where an extensive sacrifice of bone has been inevitable, and the saving of the limb has been accomplished at the expense of great shortening, the final result, when the patient has been fitted with a suitable boot, is considerably better than that of an amputated thigh; and late amputation can always be resorted to in the rare cases in which it appears useless to attempt to conserve the limb—for example, in cases complicated by an irreparable nerve injury or by persistent sinuses around the seat of excision.

The chief causes of failure of union are two:

1. A defect of operative technique—the performance of a hemi-resection of the joint, a failure to remove the articular ends of both bones, even although both may not have been involved in the fracture. A full resection of the joint should be carried out in all cases.

2. A defect in the after-treatment—too short an immobilisation of the limb. As a general rule, it may be laid down that the period of immobilisation in bed should be a full three months (longer where there has been a very extensive removal of bone); whilst on the patient being allowed up the limb should for a further three months be fixed in some form of walking splint, in a calliper or walking plaster splint.

Cases of incomplete ankylosis after compound fracture of the lower half of the femur are quite common and deserve special mention. Often there is present some 10 to 15 degrees of flexion, which, however, is abruptly limited by a bony obstacle, the result of overgrowth and deformity of the condyles. On the other hand, full active extension is sometimes lost because of atrophy or loss of substance of the quadriceps muscle.

Ankylosis in flexion (I repeat, however, that I have met with no such case among our wounded) necessitates walking in compensatory equinus. Ankylosis in this disabling position should be treated by either cuneiform resection or by a low osteotomy of the femur. This latter procedure is suitable to two classes of cases: (1) cases in which the flexion does not exceed 25 to 30 degrees; (2) cases in which it is deemed wiser to restrict the field of operation to tissues that have not been the seat of a former infection.

Nothing should induce the surgeon to attempt the performance of an arthroplasty in a case of ankylosis in good position, nor should there ever be any attempt to retain or develop mobility in cases of primary resection.

9. Ankylosis of the Hip Joint

For two reasons I will deal with this lesion but briefly, despite its great importance: in the first place, because of the considerable mortality of infected wounds of the hip joint, it is of comparatively rare occurrence; in the second, its mechanical consequences, because of its association with hip disease, are familiar to all.

The position of election for ankylosis of the hip joint is, in the absence of all abnormal tilting of the pelvis, one in which the thigh is vertical, neither flexed nor extended, neither adducted nor abducted. Such a position is of course compatible with sitting with the body normally erect only when the sound buttock alone rests on the corner of a high stool. In order to allow of the patient sitting on an ordinary chair the body has to be flexed and inclined to the sound side. Standing is not at all interfered with, and the patient can walk far without fatigue, almost as well as in ankylosis of the knee joint. Walking is carried out, however, by an amount of lateral oscillation and rotation of the pelvis proportional to the general agility of the patient.

The instinctive attitude of relief adopted is during the earlier stages one of flexion, abduction, and external rotation; during the later, one of flexion, adduction, and internal rotation. On the adoption of such a position, when the pelvis is straight, the foot, hanging down at the end of the flexed leg, falls far short of the ground—enormous apparent shortening exists.

This is compensated for by an inclination and rotation of the pelvis, so that the leg is brought into a line parallel to that of the other, and the foot into contact with the ground.

Flexion is corrected by rotation of the pelvis forwards on its transverse axis; in order to maintain the balance the trunk is thrown backwards, and a lumbar lordosis results.

Abduction is corrected by a lowering of the pelvis on the affected side; in this way results a compensatory scoliosis convex to this side. The correction of outward rotation is effected by a rotation from behind forwards of the pelvis on the sound limb, whence results a compensatory reverse rotation or torsion of the trunk.

Adduction is corrected by an elevation of the pelvis on the affected side, whence results a compensatory scoliosis convex to the sound side. Internal rotation is made up for by rotation of the pelvis backwards on the sound limb, which produces a rotation or torsion of the trunk in the opposite direction.

Such positions of deformity are of quite frequent occurrence, and interfere most seriously with walking, and even with standing in anything like an erect position. The method of choice for their treatment is sub-trochanteric osteotomy. In default of this the surgeon has to fall back on correcting the apparent shortening by means of a high boot, the sole of which should slope so as to give to the foot a position of slight equinus. Such is the palliative treatment that I am at present prescribing in the case of the wounded, in whom osteotomy of a femur that has once been infected should be postponed as long a time as possible. I have indeed performed one such osteotomy, not indeed for ankylosis, but for a sub-trochanteric fracture mal-united with considerable angulation—a condition that of course has mechanical consequences identical with those of ankylosis. The final result in this case was excellent, but was obtained at the expense of a serious recrudescence of osteomyelitis.

Apart from certain very special cases of ankylosis of the hip joint, surgeons are for the most part agreed in condemning all attempts at restoration of mobility by the performance of an arthroplasty.

Moreover, the many cases of resection of the hip joint that I have seen have ended either in ankylosis that is practically complete, or else in the formation of a pseudo-arthrosis that required a supporting apparatus taking the body weight from the tuber ischii similar to that for non-union of the femur, although acting under much more favourable conditions than that. If one considers that in these cases the resection, primary or early secondary, has succeeded both in saving the life of the patient and also in avoiding the necessity for that terrible mutilation, disarticulation through the hip joint, then surely all will agree that it is a most valuable and excellent operation.

CHAPTER II

STIFF JOINTS: FALSE ANKYLOSIS

STIFF joints, in contradistinction to ankylosed joints, should be regarded as including all those cases in which the limitation of joint movement—be it slight or severe—responds to one or more of the various forms of physiotherapy, even although in a certain number some accessory surgical treatment may have to be resorted to. Such a classification is based on purely clinical and therapeutic considerations, not at all on etiological or pathological conditions; it is on that account, however, a classification of the greatest practical importance, since it forces recognition of the fact that in these cases if treatment be commenced in time and prescribed with care and judgment, disability can be prevented, or if not wholly, at least in large part, cured.

These cases, then, are grouped together on grounds of clinical resemblance; in point of fact it would be quite impossible to formulate any scientifically exact and exhaustive definition of etiological factors and pathological conditions that would cover all the cases of this group. Certainly for the most part these are more extra-articular than intra-articular; but it would be wrong to generalise too widely as regards this point.

1. General Consideration of Pathology and Clinical Characteristics

(*a*) *Lesions.*—As far as can be gathered from the study of a few chance autopsies and amputations, and from observations made during the performance of certain orthopædic operations, the lesions are in the main extra-articular, in the sense that their first most striking characteristic is the absence of any form of union, even fibrous, between the articular surfaces, and that, in the second place, such slight changes in the articular cartilage as exist in the form of irregularities, roughnesses, and vascularisation are altogether secondary, both in time and in importance; indeed, in most cases they too are for very long conspicuous by their absence.

The chief lesion consists of an induration, a thickening, an increased vascularity and retraction of all the fibrous and connective-tissue elements of the affected region—of the synovial membrane and the joint capsule, of the ligaments, tendons, and tendon sheaths, of the intermuscular and subcutaneous planes of connective tissue with the bursæ they contain. The part played in the lesion by each of these tissues varies in different cases with the anatomical conditions of the affected region; for example, in the case of the shoulder joint the chief lesion seems to consist of a peri-arthritis with obliteration of the sub-deltoid serous bursa; in the case of the finger joints, of adhesions within the tendon sheaths. The serous lining of bursæ and of synovial membranes lose their sheen and smoothness, and their surfaces come to adhere together; all elasticity and suppleness disappear from the layers or planes of the connective tissue, which thus comes to form an unyielding cylinder of hard retracted tissue surrounding the bone so as effectually to interfere with the movement of the joint. The skin and subcutaneous tissue also play their part in the process, become thinner, tougher, and more fibrous. Thus the whole of the lesion affects merely or chiefly the extra-articular tissues; the interior of the joint remains normal or almost normal, so that the full range of the articular movement is capable of being restored when and if these extra-articular tissues become again soft and yielding.

A further and most important element in the disability, however, consists in the atrophy and paresis of the muscles controlling the joint; the occurrence of this is to be constantly noted in civil surgery; whether of direct or reflex origin, such muscular lesions are equally constant and far more serious in the case of war wounds. I will, however, deal with these in a separate chapter.

As soon as the limit of the actual range of voluntary movement is reached, the least attempt to increase this range by passive forcing of the joint becomes excessively painful. So, too, the mere exercise of tension on one of the bony levers of a completely stiff joint is productive of great pain, and that although not the slightest passive movement has been induced. Moreover, the very occurrence of this pain often constitutes an important clinical point in differentiating between mere stiffness, however complete, and true ankylosis.

In addition, the pain thus produced possesses very special characteristics of its own, of very great practical significance and importance; although intense, it is of short duration, it ceases as soon as the tension on the retracted tissues is relaxed, even in some cases dies away before this, so that it may be said that the patient and his tissues very rapidly become accustomed to the new joint position. Especially in cases where the affected region has formerly been the seat of inflammation is the observance of such characteristics of the very greatest practical importance to the clinician; for as long as this inflammation, although latent, is still in existence, such passive mobilisation of the joint will result too in pain, but in pain that persists in a considerable degree and for a variable time after relaxation of the tension of the joint. Hence as a general rule the duration of the pain, not its intensity, may be relied upon to give accurate information as to whether, the inflammation having long since subsided altogether, the condition is clinically one of mere joint stiffness that should be treated as such, or whether the causal arthritis, latent though it may be, is still in existence—in which case rest and not mobilisation should still be regarded as the treatment indicated.

(*b*) *Clinical types.*—It will be quite unnecessary after what I have said in the preceding chapter on ankylosis to insist further on the important distinction between joints that are stiff in good position and those that are stiff in bad, apart altogether from whether the stiffness be complete or not.

Very often the stiffness is incomplete; there exists but partial limitation—of greater or less extent—of the range of movement in one or more directions; for example, in the case of the shoulder joint, extension with adduction and internal rotation is usually more limited than flexion; in the hip, abduction with external rotation more than adduction with internal rotation. This means, of course, that the tissue retraction is more marked on the side of the joint opposite to that of the limitation of joint movement.

Joint stiffness that is literally and absolutely complete is of rare occurrence. In nearly all cases it will be found possible by traction on the bony levers, if not to effect a certain slight amount of passive movement, at any rate to elicit a certain feeling of elasticity in the joint; of course such tension on the joint is inevitably accompanied by pain. This, then, serves to distinguish true ankylosis—at any rate bony, usually too firm fibrous ankylosis—from mere joint stiffness, no matter how complete this latter may appear. Usually, however, such slight amount of movement cannot be executed voluntarily; as far as active movement is concerned the loss is absolute, and in this sense cases of clinically complete stiffness are not rare.

This subdivision of cases into those of complete and those of incomplete stiffness corresponds almost exactly with the classification into cases of slight and of severe degrees of stiffness that we shall adopt when discussing the question of treatment.

(*c*) *General etiology.*—Joint stiffness may occur under two different sets of conditions; these although at first sight very different are yet in reality very closely related to each other: (1) as a sequel to a pathological joint condition, whether traumatic or inflammatory; (2) as a sequel to ill-advised immobilisation of a perfectly sound joint.

Let us glance first at the various primary pathological joint conditions that may result in stiffness of, for example, the knee joint. This joint may become stiff after some aseptic trauma followed by an effusion of blood into the joint, or after a fracture of the patella that has been wired; following a trauma that in all probability was aseptic, *e.g.* a penetration of the joint treated by arthrotomy and immediate suture; following an obscure, possibly rheumatic, hydrarthrosis; following a non-suppurative infection, *e.g.* a gonococcal arthritis; sometimes even as a result of a mild suppurative arthritis that after treatment by arthrotomy has not ended in ankylosis. In a similar manner the commoner causes of stiffness could be reviewed in the case of each individual joint; each would be found to possess its own etiological peculiarities, some perfectly explicable, others obscure. This would naturally lead on to a discussion as to the reason why, for example, stiffness so often and readily occurs after a dislocation or even a mere contusion of the shoulder joint, or from a sprain of the knee, but so rarely follows a sprain of the ankle joint or a dislocation of the hip.

Under certain definite mechanical conditions absolutely identical lesions—quite as serious in their effects—can, however, be induced in perfectly intact normal joints; and if we wish thoroughly to understand the pathogeny and the prophylaxis of such joint stiffness, it is of the utmost importance that we should pay special attention to the study of those conditions that are responsible for so much joint disability; always bearing clearly in mind, however, how trauma and inflammation themselves have so constant a tendency to end in joint stiffness.

2. Pathogeny: Preventive Treatment

(*a*) *Pathogeny.*—The first point to remember is this, that if kept fixed in one permanent position any joint will in time become stiff, although the actual period of immobilisation necessary for this, and the degree of the resultant stiffness, will be found to vary not only in the case of the different joints of the body, but in the same joint with the presence or absence of certain factors whose influence it is important we should now study.

1. In the first place—age; briefly put, the older the patient the more readily do the joints stiffen; this is a fact not only well known, but absolutely true. Connected with this factor of age, too, is that of a constitutional tendency to that obscure disease, rheumatism; the joints of a "rheumatic" person, although they show no previous signs of a chronic "dry" arthritis, are nevertheless especially liable to become stiff after quite a relatively short period of immobility. In a child a sound joint that has been kept for many months in one position will often in a few weeks regain its normal range of movement, and that spontaneously, merely with use and without the help of any special treatment. A good example of this is the rapid recovery of movement in a knee joint that has for long months been immobilised in plaster with a tuberculous hip. Compare with this the condition of stiffness into which an adult's knee joint gets when kept extended merely for a few weeks, as, for instance, during the treatment of a fractured femur. This factor of age is of the greatest importance, for a considerable proportion of our wounded in this war are well over thirty.

2. It is commonly held that small, closely set joints like those of the fingers have a special liability towards stiffness. On the other hand, however, peri-arthritis with stiffness of the shoulder joint can hardly be considered as of rare occurrence. I believe that the apparent predisposition of such and such a joint to stiffness depends on (1) its relation to certain special peri-articular anatomical structures, *e.g.* serous bursæ and tendon sheaths; (2) the extent to which it becomes necessary for the patient, when the joint is freed from all external restraint, to make use of it in the actions of everyday life; (3) whether the primary position of the joint at this moment of release is favourable or not to the performance of these acts. When this position is favourable the patient will soon learn to make use of the joint; when unfavourable, he will almost inevitably find some way of dispensing with its use, and so the stiffness will not only remain, but grow progressively worse. In addition, it is precisely this attitude of functional disability that specially predisposes to the occurrence of stiffness; the rationale of this I will now explain.

3. The position in which the joint is immobilised is the most important factor in the production of stiffness.

When dealing with the subject of ankylosis I have indicated to the best of my ability the position of election in connection with each of the most important joints of the limbs; and also in addition the instinctive attitude of repose or relief adopted during inflammation, which, unless precautions are taken, becomes the position of ankylosis—a position almost invariably unfavourable to the future function of the limb. We must now determine what the instinctive assumption of this position really means and why it so specially predisposes to the occurrence of stiffness.

By injecting fluid into joints under pressure by means of a needle passed through one of the epiphyses, Bonnet of Lyons has shown that, at the moment when any further injection would result in bursting the joint capsule, the joint becomes absolutely fixed and rigid in a certain definite position, constant for each joint. This position then represents the maximum capacity of the joint, in other words, the maximum distension of the joint capsule, a degree of distension that would be quite impossible to obtain by any but a very slow and gradual distending force. If now, without changing the position of the joint, the fluid be evacuated, this condition of extreme distension of the capsule will give way to one of extreme relaxation; and as previously some of the fluid had penetrated between the bone surfaces, these will now be found to remain some little distance apart. Now it is a well-known fact that certain joint positions that are not well adapted to the functional requirements of the limb are just those not particularly remarkable for their mechanical stability; for example, lateral mobility of the elbow and knee joints is quite marked in the position of 135 degrees of extension, whilst with full extension of the knee joint and with flexion of the elbow to a right angle no such lateral mobility will be found to exist.

Actual cases of extreme distension of the capsule of the knee joint, as, for example, by hæmorrhage, will very frequently be found lying on their affected side, the knee fixed and rigidly immobilised in this position of 135 degrees of extension. It may be argued that in cases of the most abundant effusion ever met with the knee often remains quite as freely movable in all directions as on the sound side. Such extreme effusion, however, always takes place gradually and with no great violence, for ligaments, being composed of fibrous tissue, will always tear rather than be violently stretched, but under the action of a persistent gradual distending force they will yield readily enough. Certainly a sudden acute effusion as from a hæmorrhage does not exert a force comparable to that realisable by artificial injection with a syringe —a fact that serves to explain why the position assumed clinically by the joint never quite coincides with the experimentally produced standard position of Bonnet.

In acute arthritis, moreover, the effusion is never quite so abundant nor takes place so suddenly as in a hæmorrhage ; but the final result is much the same ; the patient, in order to relieve the pain, instinctively relaxes the tissues as far as possible so as to avoid all unnecessary increase of tension or pressure ; consequently the joint is held immobile in the position of its maximum capacity, a position that at least approximates to that produced by experimental injection.

Now let us inquire how it is that this position, always as regards the future function of the limb a mal-position, in itself predisposes to the occurrence of stiffness, of future limitation of the normal range of movement of the joint.

Distended, and hence destined on the subsidence of the effusion to become relaxed to their utmost, the ligaments in relation to the joint, little by little shorten, adapt themselves to the new distance that separates their points of attachment; so that if this same position of the joint be maintained for some time it will soon become a permanent one, the relative position of the bony levers to each other becoming, through the retraction of the ligaments, a fixed one.

Where, on the contrary, the joint is immobilised in a functionally good position, the ligaments can undergo shortening only on one side of the joint; on the opposite side their retraction is prevented by their being kept on the stretch by the immobilising force. Thus in extension of the knee joint as in flexion of the ankle, the posterior ligaments remain taut and cannot retract; the danger in the case of these two joints being of course the occurrence of a contrary state of affairs, viz. the adoption of the positions of flexion of the knee and of extension of the foot both of which would allow of permanent retraction of their respective posterior soft parts.

4. So far we have been dealing with the conditions predisposing to the development of stiffness in previously sound and healthy joints. It is obvious, however, that, other things being equal, this predisposition will be greatly increased in cases where certain various pathological lesions exist in or around the joint:

(*a*) Where although the joint itself remain intact there exist inflammatory changes or œdema in the surrounding soft parts. An example of this is the stiffness that occurs so rapidly in all the finger joints with a cellulitis of the palm of the hand.

(*b*) Where there has occurred some definite lesion, no matter how superficial, of the joint itself, either in the nature of a sprain or contusion, especially where the latter has been associated with an effusion of blood into the joint (knee), or around it (shoulder), or else of a slight actual arthritis, aseptic or even mildly infective.

(*b*) *Preventive treatment.*—I have already sufficiently well indicated in the case of each joint the position of election for immobilisation.

It should also be now quite clear how important it is that the period of immobility should always, and especially in the case of healthy joints, be as short as possible.

1. *Immobilisation and mobilisation in the case of sound joints.*—It is impossible absolutely to immobolise a fracture without including in the plaster or splints its two adjacent joints, the one above and the one below the seat of the fracture. Now, although the opposite practice of dispensing with such joint fixation has its champions and adherents, yet the necessity for it is absolute, at any rate during the transport of compound fractures to the base; the earlier the patient is moved the more essential this becomes, the more efficiently should it be carried out. Such complete immobilisation is the best preventive of the spread of the infective inflammatory process, and the best means of avoiding such secondary complications as the laceration of large vessels by spicules or sharp fragments of bone; hence the practice of evacuating all compound fractures in extensive plasters, with windows cut for dressing the wounds, or else the various segments of the plaster united by bridges and bars of metal. These plasters include the whole of the wounded limb; in the case of a fractured humerus, for example, the shoulder, the flexed elbow, and the wrist are all included and

immobilised at once, immediately after the performance of the primary operation at the front.

But as soon as possible this extensive plaster should be removed; such absolute immobilisation of the seat of the fracture is not at all necessary for the attainment of union (because of this some surgeons have wrongly concluded that there is no need for the immobilisation of fractures at all). The fractured bone should be fixed in simple splints that allow complete or at least partial freedom of movement to the adjacent joints. This the walking splint devised by Delbet for fracture of the leg allows to the knee joint and to the joints of the foot; in fracture of the bones of the forearm a well-fitting and perfectly efficient gutter splint need fix neither the elbow nor the fingers; for fractures of the humerus and femur the continuous extension apparatus introduced by Delbet or one of its numerous war modifications is practically ideal.

Similar treatment should be adopted as regards the mobilisation of the rest of the limb in cases of suppurative arthritis of one joint; as soon as the acute inflammatory complications have subsided, the suppuration has moderated and the injured joint has become free from pain and all peri-articular swelling disappeared, movement of the neighbouring intact joints should be freed from all restraint. This presents quite a simple problem to a surgeon who knows how to apply plasters, whether in bandage or in splint form.

In the case of mere flesh wounds the reasons for setting joints free as early as possible are still more cogent. How often does one see not only in military but in civil cases the whole hand bandaged for a lesion limited to one or two fingers. The extent and size of such a dressing is bad, in that it magnifies the importance of the wound in the eyes of both the dresser and the patient; this apart altogether from the question of the financial results of such extravagant use of cotton-wool, gauze, and bandages: the immediate expense of the material and the extra and needless and quite avoidable expense of the additional pension that will become necessary on account of the stiffness of joints and the wasting of muscles that are going on beneath the cramping and voluminous mass of the dressings. Let the dressing, then, always be light, let its size bear a reasonable relation to the extent of the wound, let the quantity of the cotton-wool be merely sufficient to absorb the discharge, for it should always be remembered that free entrance of air to the wound can never have any but a beneficial effect. There can, too, be nothing worse than the constant application of wet dressings to the hand or the foot.

2. *The immobilisation of injured joints.*—Having said thus much concerning the treatment of joints not actually involved in but merely contiguous to wounds, I must now deal with the question—often one most difficult to decide—as to when a joint that has been actually involved in the lesion should be immobilised, when free movement and active use should be allowed to it.

In the case of a contusion or a sprain immobilisation in plaster is never called for; all that is necessary is tight bandaging over a layer of cotton-wool so as to exercise firm and equable pressure; whilst in order to prevent wasting and atrophy of the limb, immediate care and attention should be focussed on the condition of the muscles; where the joint is filled with blood—as is usual in the case of the knee joint—this should be aspirated; and from the outset the patient should be encouraged to commence gentle, active movement. I am not at all sure, however, that the modern practice of allowing the patient to walk at once is wise. Such is no doubt all very well in cases where no actual laceration of ligaments has taken place, but as in most cases such laceration has occurred, too early walking (I mean before the eighth or tenth day) without a bandage or splint to keep the knee extended involves, in my opinion, a serious risk of permanent laxity of the ligaments with a consequent development of excessive lateral mobility. Examples of this sequence of events are not rarely seen at the Grand Palais.

As to cases of actual joint inflammation, whether spontaneous in origin or the mild non-suppurative form that remains after arthrotomy for an aseptic trauma, it becomes a matter of clinical experience and judgment to decide when the pain provoked by pressure or movement has become sufficiently slight, when all effusion has disappeared from the joint, to determine when resumption of the normal function of the joint may be cautiously commenced. In such cases it is the duration of the pain, and not its intensity—this is always at first extreme—that is to be taken into account as of such very great practical importance.

3. *The resumption of normal function.*—It is not sufficient, however, to free the joint from all external restrictions: it is necessary that the patient should make full active use of it. Now he always has an instinctive tendency in order to avoid pain to keep

himself from using the limb, and this even where the wound has been but a slight one of the soft parts only. The surgeon's attention should be directed to this matter, both during the period of the patient's confinement to bed and when he begins to get up.

In many cases of wounds of the upper limb the tendency of the patient while lying in bed is to keep the limb alongside the body, the elbow in full extension (a deplorable position), and the forearm in pronation (which is hardly less deplorable), and the wrist and fingers either fully extended or semi-flexed ; in other cases, to keep the arm across the body with the elbow more or less flexed ; in this position certainly the degree of the pronation is much less, but inevitably the wrist falls into the bad functional position of flexion.

As regards the lower limb, whether the patient lie in bed on his back with the knee fully extended or on the affected side with the knee flexed, the foot invariably drops into a position of equinus with more or less of varus, and this in time becomes associated with the development of clawing or hyper-extension of the toes (a deplorably bad functional position); this position results as much from the weight of the foot and of the bed-clothes as from the weak and relaxed state of the muscles of the leg. With the patient occupying either of these positions the wearing of a right-angled bed shoe or of a back splint is most important, for such gives vertical support to the sole, and also serves to keep the weight of the bed-clothes off the foot.

In addition, in both the upper and lower limbs it is most necessary from the outset to adopt the performance of daily movement of the fingers or toes, of the wrist or of the ankle; such may be carried out passively and through a gradually increasing range every day whilst the patient is being washed or his wound dressed. Very soon, however, should such passive movement be supplemented and in time replaced by corresponding active movement, should the patient begin to exercise his fingers by grasping a successively smaller and smaller object (a ball of string, for example), should the foot be brought to the right-angled position as soon as it shows the least tendency to fall into equinus—this by means of a loop of bandage passed round the foot on which traction can be exerted either by the patient himself or by attachment to an elastic band, for example, an ordinary piece of rubber tubing.

Instead of such rational treatment, however, too often the patient is got out of bed—of which of course he is tired, and in which he is supposed to be losing strength—and given a sling or a pair of crutches! With what result we shall see.

(*a*) *The use of slings.*—The moment a patient wounded in the arm comes to sit up in bed he is nervous and anxious about his wounded limb, its weight causing him discomfort; indeed at this stage full extension of the elbow so that the limb can descend alongside the body is impossible. In too many cases the result of this is the adoption of a sling, too often a sling that envelops and supports, not simply the wrist and forearm, but the whole arm, fixes and immobilises it firmly to the front and side of the body, the elbow flexed to a right angle, the forearm in semi-pronation, the wrist flexed to somewhere near 45°, and the fingers either fully extended or semi-flexed. Fixed in this position the limb remains not only throughout the day but during the night as well, so that shoulder, elbow, wrist, and fingers soon become definitely and obstinately stiff.

A sling that allows of full use of the fingers is better, provided that care is taken to assure daily movement of the fingers and hand; otherwise the wrist will become fixed in adduction and the fingers remain inert and extended.

What is necessary in these cases is a simple loop, which, pinned above to the sound shoulder, affords a temporary and occasional rest to the hand and arm; the patient can use it or not at will, and in removing and re-inserting his hand a certain amount of movement of the elbow and the shoulder is inevitable; little by little the patient becomes accustomed to and able to perform the common actions of everyday life, as, for example, eating and drinking. No doubt at first such movement will result in pain, but insist on their performance and you will succeed in avoiding serious stiffness.

Of course no one will expect in this way to avoid loss of function due to actual destruction, fibrosis, and retraction of muscle. But that is no reason why one should allow an additional and quite avoidable disability to become superimposed on what is inevitable and possibly irreparable. Such stiffness of joints as results from immobilisation in a sling is by no means invariably or necessarily the result of sepsis. One of the finest, or rather one of the worst examples of this type of stiffness that I have ever seen was that of a woman whose arm a charlatan (qualified nevertheless) had immobilised in a sling after vain attempts to reduce a dislocation of the shoulder joint; her nails were fluted; her fingers stiff in extension; the skin of the hand thin and shiny; the wrist joint fixed at 45° of flexion and the elbow at 135° of extension; the disability could hardly be more complete, without taking into account the complete stiffness of the shoulder and the compression of the brachial plexus.

(*b*) *The use of crutches.*—Correspondingly similar considerations arise in the case of cripples who cannot walk except on crutches. Such patients get about with the foot dropped and with consequent compensatory flexion of the knee; whilst lying in bed—always of course on the affected side—the leg is kept in the same fixed position, the foot in equinus and the knee flexed. Many surgeons no doubt consider that such patients will be benefited by giving them crutches, by getting them up and about; as a matter of fact such treatment usually results in a more absolute fixation of the foot and in a more rapid development of stiffness than if the patient were strictly confined to bed and kept lying on his back. It is true that by getting up the patients get more general exercise and fresh air, but too often at the expense of a foot stiff in equinus and of stiff hyper-extended toes. The drag of the weight of the leg and foot is usually sufficient to prevent the knee joint from becoming quite stiff; stiffness of this joint was successfully accomplished, however, in one case that I have met, in which in order to relieve the patient of all effort the foot was slung by a band to the waist-belt.

Other surgeons go to the opposite extreme and refuse to allow their patients up until all their wounds are healed. This is of course logical, and in theory ideal; but its realisation involves difficulties that are not compensated for by the benefits gained unless one can succeed in considerably shortening the ordinary period of healing. Before, however, any patient is allowed to walk his wounds should certainly be almost healed, and his joints, especially those of the foot and toes, supple and in good position, so that the sole can be brought into normal relation with the ground; even under these conditions the patient must be trained to make active use and to take active control of each of the joints of the injured limb. The ideal course would be to allow the patient to walk only when he is capable of so doing correctly and with the assistance merely of a stick. But of course one has to compromise and allow two sticks or a pair of crutches, but this should be done only on condition that they should be used solely to assist the limb in bearing the body weight, and on no account to relieve it of all active effort and use; walking on one leg and a pair of crutches should never be allowed. For example, there is no reason why a patient fitted with a walking apparatus for fracture of the leg or thighs should not be given crutches provided that his foot is normal; but there is every reason in the world why they should not be allowed in the case of a patient whose foot, no matter how slightly wounded, is fixed still in even the slightest degree of equinus.

3. Curative Treatment

Restoration of mobility in the case of stiff joints may be effected (*a*) by certain indirect methods, (*b*) by one direct specific method—movement itself.

(*a*) *Indirect methods.*—These I will do no more than enumerate. In the first place, massage is one of the most important and one of the most effective—massage both of the peri-articular tissues, which thus become less œdematous, and massage of the muscles, which serves to prevent their atrophy either altogether or at least in great part; indeed in this latter respect I believe massage to be very greatly superior to electrical treatment. Frequently repeated voluntary contraction, even though purely static, of the muscles around an immobile joint is also a most valuable method of maintaining muscular tone and development and preventing atrophy.

Daily immersion in hot water (about 112° F.) is certainly of value in increasing the mobility and suppleness of a stiff joint; careful record should be kept of the range of movement possible when the limb is actually in the bath, especially as, when under water, the movement of the limb becomes easier in accordance with the principle of Archimedes. In place of such baths or alternating with them one may make use of the hot douche.

What are we to conclude concerning the therapeutic value of the addition to the hot water of sulphur or various mineral salts? The answer to this must remain for the present undecided. I believe that certain continuously active mud baths contain minerals the beneficial action of whose chemical and physical properties, although the exact nature of these remains obscure, cannot be denied. But in the case of the ordinary mineral baths it would seem that the addition of the chemical agents has but little therapeutic significance.

Each spa, of course, extols the virtues of its own particular waters; but as each is in turn described as the most "radioactive," their exact chemical constitution would seem to be of no very great importance. The advantages to be derived from such spa treatment are probably due in part to the warm water and in part to these centres being well equipped for general physiotherapy.

I am not at all convinced, moreover, that either ionisation or radium therapy is of any special value whatever; certainly they are of no greater value than most of the numerous agents that we are being continually asked to accept as specifics.

(*b*) *The direct method.*—Movement is the great specific for stiff joints: when prescribed at the right moment, and regulated both as regards duration and force, it is a therapeutic agent of the greatest value.

The correct moment when mobilisation of a stiff joint, previously the seat of inflammation, should be commenced is that at which the pain induced by it, though often intense, does not persist after the movement has come to an end. In many cases the passive mobilisation of a stiff joint will be found to result in a recrudescence of the inflammation; such inflammation should be treated in the usual way, *i.e.* primarily by rest, all further movement for the time being interdicted. In other cases, however, the mobilisation should be repeated as frequently as possible and as is compatible with the character and duration of the pain. These rules apply equally to all the various methods of mobilisation that we have at our disposal.

Thus the movement may be active, executed by voluntary contraction of the muscles normally controlling the joint, or passive movement mechanically communicated to the joint by the patient himself, by an operator, or by means of a machine. Such passive movement will be either gentle and progressive or sudden and forcible. The former method usually suffices where the degree of stiffness is but slight; after a short trial it is usually very easy to decide whether the case is going to yield to such daily gentle manipulation or not; in the latter case it is no use wasting time by persisting with it; in such cases, cases really of severe stiffness, forcible mobilisation should be resorted to at once. This distinction between slight and severe degrees of stiffness should not be construed as synonymous with that between stiffness of small and large joints. We will first study the treatment of the simpler cases—of joints stiff in good position; later, the correction of joints that have stiffened in mal-position.

1. **Joints Stiff in Good Position.**—In such the object of treatment is simply restoration of the normal range of movement.

(*a*) *The treatment of slight degrees of stiffness.*—In the case of slight degrees of stiffness the chief therapeutic agent should be active movement; no case should be treated by passive mobilisation alone; such should always be at least supplemented by active movement. In some cases such mobilisation may result in a more or less marked degree of reaction.

When a patient with a stiff joint—the result or not of an attack of arthritis—is first set free from splints, allowed to commence movement and active use of the limb, we have to depend to a great extent on the spontaneous progressive return of movement, effected both by voluntary or reflex muscular contraction and through the influence of such passive external forces as gravity, and the forcible and inevitable shocks and communicated movements of everyday life.

The mechanical conditions are different in the case of the two limbs; in the case of the upper its own weight constantly tends to straighten it out, but as soon as the patient puts his foot to the ground the body weight, acting in a reverse direction, from below upwards, has the opposite tendency. But in the case of both limbs it becomes necessary to supplement voluntary movement, always at first very slight in range and weak in strength, and constantly limited by fear of pain, by involuntary passive movement, which, being sudden and forcible, is always extremely painful. Such passive movement is alone capable of breaking and reclaiming new ground, ground that is subsequently gone over and retained by the ordinary active voluntary movements.

Such a sequence of events may result more or less accidentally by the occurrence of a certain amount of "false movement" during the ordinary routine of daily life, movement active or passive induced in the limb at a moment when the patient is least expecting it. In some slight cases the régime of the patient's ordinary work may be relied upon to induce sufficient movement to bring about a cure. But except in very slight cases it would be unwise to trust to this. In most cases the patient should be set to perform regular and methodical exercises, modified and suited to the needs of each particular case; and for this purpose he should be instructed how to make use of the ordinary articles of his home as agents of passive resistance.

Commencing with the upper limb, let me give some examples of this "home mechanotherapy."

In the case of the shoulder joint the range of its two most important movements—abduction and internal rotation—can be very easily and simply increased; twenty-five years ago I gained for myself in the course of a week quite a small reputation at the expense of a bone-setter, who had reduced a dislocation of the shoulder (in which, by the way, a doctor had failed) but had made the mistake of immobilising the arm in a sling for a month, after which he did not know how to set to work to get rid of the stiffness, to regain for the patient the power of abduction of the arm.

The following would be my instructions to such a patient: Sit down parallel to a table and rest the point of your elbow on its edge and then gradually and slowly move your body further and further from the table, keeping, however, the elbow in position; in this way you will passively open up the angle between your side and your arm. This no doubt will cause you some pain; when you feel that you can bear no increase in this, do not move any further, but without actually increasing the angle between body and arm maintain this position for several seconds, keeping the arm and body tense; then without moving just relax the tension; finally commence to diminish the angle again, and so return to the original position; rest a few minutes, and then repeat the manœuvre, and so on.

Or stand in front of a mantelpiece, or a bookcase whose shelves will provide you with a choice of heights, and lean on your elbows in the attitude of a *beau ténébreux* of 1830, and as long as you maintain this position you will be executing, and that without anyone noticing it, exactly the same movement as in the last exercise.

You will easily understand that by making use of in turn a higher and higher support, and by gradually increasing the distance between the bottom of the bookcase and your feet or chair, and so coming to bend your body more and more, you will be exerting a progressively greater pull and tension on the tissues of the armpit.

Again, it will be perfectly obvious to you that in the first exercise you can develop the range of forward movement of the arm simply by advancing your elbow further and further in front of you along the edge of the table and moving your body not directly outwards but outwards and backwards.

I must now explain to you that when you have succeeded in elevating your arm to form an angle of 45° with the body the great part of this is only apparent gain, is due to a rotation of the shoulder blade, and only a small part of it represents actual stretching of the adhesions round the joint. But do not on that account be discouraged, for neither you nor any one with special apparatus can efficiently fix this bone so that it will not rotate. Persevere now, but with a different exercise. Sit facing, but at some distance from, the table with your elbow resting on it and flexed and your brow resting in your hand, your face turned somewhat towards the affected arm, your whole attitude that of one lost in deep thought; then pass your other hand above your head, interlace the fingers of the two hands and pull at first gently, then more forcibly, and finally passionately; in time, in order to regain the last degrees of abduction and elevation of the arm, it will become necessary for you to shift your hand to the opposite side of the head, and in addition to incline your head itself well over to the sound side. And in the course of this exercise as of all others proceed by first reaching the position of toleration of the maximum amount of pain, by maintaining and then relaxing this position, finally by returning to the original attitude and commencing afresh; in addition, always finish by giving a little extra force to the last movement.

In this exercise you have allowed the scapula to rotate to its utmost and have been exerting a direct pull on the shoulder joint itself.

You can test the range of internal rotation possible at this joint by attempting to assume the "Napoleonic attitude," the forearm being carried transversely across the small of the back. If, however, you cannot place it at once in this position, commence gradually. With the stiff limb hanging alongside the body, the thumb internal and the back of the hand facing forwards, pass the other hand behind the back and seize hold first of the thumb, then of the fingers, and finally of the outer border of the stiff limb, and gradually pull it until it comes to rest on the buttock. When this has been accomplished, begin to pull this hand up behind the back. This will result in an increase in the flexion of the elbow and in the internal rotation of the shoulder. For both these actions this position provides an excellent leverage.

Where you wish, however, merely to increase the range of elbow flexion, it is much simpler and easier to do so by supporting the forearm against, for example, the side of an armchair and then decreasing the angle between it and the arm by pushing with the whole weight of the body; as regards increasing extension, the mere weight of the arm is constantly acting in this direction, and this of course can easily be reinforced by lifting objects of different weight.

In order to increase the range of backward movement at the wrist joint, support the front of the fingers flat on a table, let the knuckle joints flex, and then push the forearm towards the table, or else with the palm of the hand flat on the table carry the point of the elbow directly forward towards the table; in a similar way the range of forward movement of the wrist can be effectively increased by forcing the back of the hand flat on the table.

Having thus at length described these methods of utilising ordinary articles of furniture as agents of passive resistance in the performance of exercises, I need not give any detailed account of how the sound limb can be constantly engaged in communicating passive movement to the elbow, the wrist, and the fingers. The general principle remains the same; the joint is stretched until it becomes too painful to proceed further, is held tense in this position for some little time, and then relaxed.

The joints of the lower limb can be exercised by weight-bearing, the agent of passive resistance being the ground; such exercises should be carried out strictly in the light of our knowledge of their normal movements during walking. (See page 63.)

There can be no better exercise than walking for gaining in the required directions the necessary range of movement at each of the three large joints of the limb—the hip, the knee, and the ankle. At the same time it will not be necessary to insist on the patient's marching exactly in the military manner; at any rate at first a little relaxation of gait may be allowed him.

I have already sufficiently insisted, in the case of patients wounded in the leg, on the importance of getting their joints supple and in good position before they commence to walk. The foot at any rate should reach the right angle, and be fixed neither in varus nor in valgus; normal walking, however, demands a degree of flexion of the ankle joint greater than that represented by the right-angled position; the foot must reach a point some 18 to 20 degrees beyond the right angle.

In order to gain these few extra degrees of flexion it is usually sufficient to explain to the patient how in walking he should see that at each step the heel is always lifted from the ground before the toes, that the knee is flexed and not held stiff in extension, and, finally, that the heel is brought again carefully into contact with the ground.

If such self-educative methods fail, an excellent exercise for increasing the range of flexion of the foot beyond the right angle consists in standing on the affected limb, the sole flat on the ground, and alternately flexing and extending the knee; under these circumstances flexion of the knee necessitates simultaneous flexion of the ankle, and the whole weight of the body, tending to close the angle between foot and leg, comes to be exerted on the retracted posterior muscles and ligaments of the ankle joint. Such an exercise can of course be repeated an infinite number of times during the day. Another simple exercise consists in standing on the sound limb and with the front part of the sole of the other foot pressing the flexed foot against a wall. Or the patient may be set to work a sewing-machine with his foot; this has the advantage that the exercise commences with the foot in the equinus position.

Riding a bicycle is also an excellent method of increasing the range of flexion of the ankle joint if the saddle be mounted low for the patient, of increasing the range of extension of the knee and hip if it be mounted high. Where the patient cannot walk—where he can, it is a tedious form of exercise—a stationary bicycle can be very easily and cheaply installed.

I have thus indicated the general principles of treatment and illustrated a few of the elementary means of their application to the conditions of particular cases. Such methods can be modified and multiplied according to the ingenuity of the surgeon to suit the need of individual cases. A more widespread adoption of this "home mechanotherapy" would be the means of a great saving of valuable time among numerous cases of our wounded.

In specially equipped centres, however, these special movements can be carried out by means of graduated apparatus, in which the patient performs each action separately against elastic or weight resistance, so that during one "séance" the special curative actions can be performed over and over again, voluntarily by the patient but at the same time methodically and under skilled surveillance. Various are the models that have been designed and constructed; it is easy, for instance, to devise an apparatus by means of which one or more fingers can be set to work in a definite prescribed way. Such apparatus, however, can do good only when and if the patient participates willingly in the work; their use should never be allowed to degenerate into the repetition of a passive action a certain number of times once a day, in the intervals between which the patient does nothing, even perhaps falls back on the comfort of his sling or crutches and all the habits of immobility that they represent.

As soon as the joint becomes capable of a certain range of active movement the best of all treatment consists in a resumption of manual work—a resumption at first of course but partial, in time as power and range of movement increase a resumption in full. "This is mechanotherapy ten hours a day," as one of my patients remarked to me. Since we have come to recognise that we were for long on the wrong track, all now are coming round to the view that manual work is of the very greatest benefit to the wounded—a view that during the early days of the war was not at all received with favour. In this connection, re-educative works have been most valuable; re-education in town trades has been facilitated; the centres for education in agricultural work have been the means of converting many men formerly merely unskilled day labourers into skilled agricultural workers.

In the great majority of cases the daily use of the hands during work is of infinitely greater curative value than any amount of treatment by such purely passive agents as I have now to describe.

All passive movement—movement communicated to the joint by some external agent—should be regulated on the same general principle, the limit of movement marked by the commencement of pain should be reached, and the tension maintained for some seconds so as to stretch the retracted and shortened ligaments; especially in those directions that are to prove most useful and against those ligaments considered most resistant should such passive movements be carried out.

Manual mobilisation by a skilful operator is by far the best method of executing these passive movements, far better than by any machine; especially is this manual method valuable when combined with such aids to muscle development and training as massage and resisted exercises. In resisted exercises particularly can the amount of muscular work performed be better graduated than when the movement is executed against the force of a mere lifeless spring or elastic band; such exercises have the additional advantage over mechanical methods that the operator knows at once whether the patient is putting his heart into the work or is merely performing it perfunctorily. But good operators, skilful and intelligent, are not common, and there are many hundreds of wounded to treat; their number renders such individual treatment in all cases impossible.

Hence we have to fall back on mobilisation by mechanical means. The first types of machines were invented a long time ago, *e.g.* the old-fashioned machines of Louvrier, in which the two levers of the joints were embraced by two cuffs that were united by a hinge and a pulley arrangement allowed the patient or an operator alternately to exert and to relax tension on the joint. This type has been successfully modified to include the principle of continuous elastic traction, whether by coiled springs or by bands of rubber tubing, etc. Since the war P. Robin has designed a series of very ingenious apparatus which, though I am sure he is wrong in regarding them as working appliances, yet seem to me to be admirably suited for therapeutic purposes.

The ordinary type of apparatus which nowadays is in such demand in certain "institutes of mechanotherapy" is, in my opinion, far inferior to those I have just mentioned. In this type of machine the upper lever of the limb being immobilised, the lower fixed in a cuff is worked backwards and forwards in a definite direction by means of an electric motor; such a method fails to realise the important principle I have so often insisted on—the steady maintenance of that position that corresponds to the limit of toleration of pain by the patient. In addition, all voluntary effort is entirely eliminated, and the patient has thus less direct and attentive interest in the movement than has a beggar in that of his barrel-organ. With no effect on tight adhesions such apparatus is equally useless after such adhesions have been broken down, and so is very greatly inferior to carefully regulated gymnastic exercises.

(*b*) *The treatment of severe degrees of joint stiffness.*—In some cases all these means fail; either they can create no such slight range of movement as may act as a starting-point for further gain, or else after a certain amount of improvement a point is reached beyond which progress becomes stationary. In all such cases there is no use in persisting with these methods; the way should be prepared for them by a preliminary forcible mobilisation carried out at one sitting. Such—it must be understood—will never by itself result in cure; what one aims at by forcible mobilisation is merely the conversion of a case of severe stiffness into one of slight, which must then be treated on the lines we have just laid down.

Special attention should be paid to the correct technique of forcible mobilisation.

After steadying the upper segment of the limb the surgeon should always commence by forcing the lower segment in the direction that offers him the better leverage; this in the case of the knee and elbow joints means an increase in the degree of flexion. A slow, gradual, and steady force being exerted on this free segment of the limb, the adhesions will be felt to crack and give way at first slowly, but soon more quickly and easily. A series of alternate movements in opposite directions should now be carried out; each successive movement should carry the joint a little further in its direction than the preceding one; in the case of ball-and-socket joints the performance of circumduction should not be forgotten, and the surgeon should not desist until the full normal range of each movement has been realised.

If one judges by the appearance of patients in whom by a trick of the thumb we have suddenly flexed or extended a stiff finger or toe, forcible mobilisation is an extremely painful operation. Hence it is necessary to give an anæsthetic—chloroform or ether in the case of one of the larger joints where the manipulation will certainly take some time, ethyl chloride for the smaller joints where the operation will be of but short duration.

I have never been able to see any advantage in using special apparatus for forcible manipulation of joints.

When the operation is completed the joint should be fixed in good position and lightly but firmly bandaged for several days; the joint region swollen and bruised will be very painful, but slight active and passive movement should be commenced at once, later the full treatment instituted as for cases of slight degree of stiffness.

2. The Treatment of Joints that are Stiff in Mal-position.—Cases of stiffness with slight deviation from the position of election hardly need to be specially considered; they usually yield to treatment on the lines laid down for cases of slight stiffness in good position, although perhaps rather more than usual importance should be attributed to the efficient performance of the corrective exercises. Where the deviation is one of rather greater degree the surgeon will have to have recourse to one of the methods of elastic traction already described.

The two chief genuinely surgical methods that have to be relied on in all cases that are not amenable to these milder forms of treatment are (1) gradual correction in stages and (2) forcible correction.

Gradual correction in stages by a succession of plasters, a classical method in orthopædic surgery, consists in obtaining at each sitting as much correction as possible, and in maintaining this by manual pressure or elastic traction until the limb is immobilised in plaster. At the end of a fortnight the retracted elements will be found to have yielded somewhat, so that a further gain becomes possible. I will not enter into details of the technique of this method, because I have never had occasion to use it in war surgery. Its great advantage is that it avoids the necessity for an anæsthetic; against this, however, is to be put the length of time over which the treatment has to be spread. In addition, in the majority of cases we meet nowadays among the wounded the stiffness is of a severity that will not readily yield to this form of treatment.

Forcible correction of the position of a joint under an anæsthetic is, as regards its technique, but not as regards its aim, identical with the operation described above as forcible mobilisation of a joint. The operator should always commence by exaggerating the deformity; in other words, he should proceed first to break down the adhesions on the side of the joint where the ligaments and soft parts are the less retracted. The advantage of this is that it gives greater freedom of movement and greater momentum for the attack on the more dense adhesions and the more strongly retracted ligaments on the opposite side of the joint—the tissues that are really responsible for the maintenance of the mal-position. The surgeon should be satisfied and desist only when a position has been reached that constitutes a slight exaggeration of the required correction.

In the case of stiff fingers—stiff in flexion or in extension—and of stiff hyper-extended toes a much more simple procedure suffices; the correction can be effected by a single sudden twist of the surgeon's fingers. When thus forcibly extending a finger or a toe the surgeon will often feel something give way with a crack; at the same time a tight band or cord will become evident in the forearm or leg; one's impression is that adhesions between tendon and tendon-sheath have suddenly snapped, with a consequent sudden transference of the force of the manipulation to the freed tendon and its muscular belly. Very often after such forcible manipulation of fingers it is quite remarkable, once the extreme initial pain has subsided, how free from pain any passive movement of the fingers now becomes, even though carried out within a few minutes of the performance of the operation. Occasionally in the case of the toes forcible correction results in a transverse tear of the retracted skin across the bottom of the groove separating the plantar surfaces of the toe and the sole.

I have only once had to perform forcible correction and mobilisation for simultaneous flexion of both the wrist and the fingers, in a case in which the extreme flexion brought the tips of the fingers into contact with the palm of the hand. But very numerous are the occasions on which forcible correction of the various joints of the foot becomes necessary, joints for the most part stiff in equino-varus, whether the stiffness be simple, complicated by retraction and shortening of the tendo Achillis, or of a primarily paralytic origin. Where the stiffness is the result of or accompanied by muscular retraction or paralysis, the forcible correction will have to be followed by operative treatment suitable to the concomitant lesion or disability. Division of the tendo Achillis in particular is very frequently indicated, indeed practically always; where it is not performed, the force used in the correction of the equinus will very often result in a tearing of the tendon from its point of insertion into the os calcis. The performance of a tenotomy is preferable to this.

The differences in after-treatment and results between this operation of forcible correction and that of forcible mobilisation are great; after the former operation the limb should be immobilised in plaster for about three weeks in the corrected position. For the next fortnight the patient should be made to walk about in the plaster, the sole of which may if necessary be specially reinforced. Although in some cases it will be wise in order to avoid all risk of recurrence of the equinus to prescribe an appliance with elastic traction for night wear or during walking, in the majority of cases no such support will be necessary. In some cases a variable amount of restoration of mobility will eventually take place; in the majority, however, such is not to be looked for, the ankle joint remaining permanently stiff in the right-angled position. If the slightest amount of varus remain uncorrected, the influence of the body weight will inevitably and progressively increase this, and no appliance or surgical boot that can be ordered will succeed in preventing it. In cases where the sole has been brought into its normal relation with the ground nothing can increase the range of mobility of the foot better than walking (see page 68); on the other hand, if the foot be deviated the least little bit into varus nothing will make it worse so surely or so rapidly.

Where there persists not indeed any actual varus but however slight a tendency to its recurrence, the outer part of the sole of the boot should be raised (see p. 61).

Sometimes full correction of the equinus cannot be effected at the one sitting, the foot cannot be got quite to an acute angle with the leg; such persistence of the slightest degree of equinus will almost certainly result in a relapse of the varus.

Moreover, since such forcible correction results in the foot remaining tender for some time, when the patient first commences to walk he very often exhibits a tendency to walk on the outer border of the foot; such a tendency should be checked at once.

The case should then be treated as a case of but a slight degree of stiffness.

In cases where the deformity has been marked a night shoe should be ordered (in some cases indeed it may be wise to insist on the patient wearing an appliance during walking for some weeks at least);

this shoe, which should be fitted with elastic traction, should consist essentially of a sole piece and a leg piece connected together by a hinge behind the heel and by two elastic bands or coiled springs that pass one on each side of the ankle joint.

In any case the patient should certainly have the outer border of the sole of his boot raised so that he walks in slight valgus; indeed such a boot should always have been prepared in advance so as to be ready for use as soon as the patient comes out of the plaster.

Gymnastic exercises to increase and maintain the range of flexion of the ankle joint as well as careful re-education in walking should always be carried out; this latter is an infinitely more valuable method of treatment than any amount of passive mechanical exercises.

The position of the foot being thus corrected, massage should be now commenced to lessen the œdema and to increase the strength and development of the wasted muscles; such treatment which before, on account of the deformity and inability to walk, was useless can now prove of the very greatest advantage. Hence the following up of an operation of no very great severity with such valuable forms of accessory treatment should in the course of eight to ten weeks result in the conversion of a deformed and useless foot into one whose range of movement it is true remains more or less limited, but in which the range of flexion is sufficient and well adapted to walking, in which the sole can be brought into normal relation with the ground, and through which the transmission of the body weight causes no pain.

The forcible correction of such a foot, however, is in many cases neither a simple nor a short operation; it often takes an experienced surgeon from fifteen to twenty minutes; hence for its performance ethyl chloride is not a suitable anæsthetic; either ether or chloroform is necessary.

The classical precept, laid down somewhere about 1860 by Adams, and re-discovered time and again since then, insists that first of all the varus element of the deformity should be corrected before the equinus element; in this way the elevated posterior tarsus is used as a fixed point against which the force necessary in the manipulation of the mid-tarsal joint may be exerted. After the full correction of the varus the equinus should be next attacked, care being always taken that the correction is effected at the ankle joint—which means real correction, with a lowering of the heel—and not at the mid-tarsal joint, hyper-extension of which results in an apparent correction that does not alter in the least the elevation of the heel. Finally, any hyper-extension of the toes should be dealt with. Sometimes, too, a co-existent stiffness or deformity of the knee joint may require attention.

1. *Correction of the varus.*—The foot should project somewhat beyond the edge of the table whilst an assistant holds the leg firmly and steadily with the knee fully extended. The surgeon should then face the foot, and with one hand—the right in the case of the left foot, and *vice versa*—fix the posterior tarsal bones and ankle joint; with the other he should grasp the anterior part of the foot, the fingers on the dorsum, the thumb across the sole, and commence as usual by increasing the deformity—the extent of

the varus; the fore-part of the foot should be then suddenly and forcibly wrenched into valgus, the force being chiefly exerted through the thenar eminence of the surgeon's hand to the anterior part of the first metatarsal bone. This sudden jerk should then be followed by firm, steady pressure in the same direction, a pressure into which the operator standing with his elbow flexed to a right angle and buttressed against his side should put the whole weight of his body; in the meantine his other hand should draw the posterior tarsus in the opposite direction. It should never be forgotten that in accordance with the shape of the articular surfaces of the mid-tarsal joint the fore-part of the foot should in the correction of varus be forced upwards and outwards as well as externally rotated, should in the correction of valgus be pulled downwards and inwards and internally rotated.

2. *The correction of the equinus.*—It now becomes necessary to deal with the ankle joint, and that in the following manner:

Grasping the posterior part of the foot between his two hands, the fingers crossed on the dorsum and the thumbs meeting on the sole, the surgeon should gently draw the foot as far into equinus as possible and then suddenly and violently wrench it in the opposite direction as far as possible into calcaneus; during this stage of the manipulation strong adhesions will usually be felt to give way. The operator should take special care to apply the force through his thenar eminences to the under surface both of the mid-tarsal joint and particularly of the os calcis itself, for it is most necessary to ensure full correction of the position of this bone, to raise its anterior end and so to depress the heel. When a certain range of movement has thus been obtained in the ankle joint, complete correction of the equinus should be effected in the following way: whilst keeping the knee extended the assistant should raise the whole limb to an angle of 45 degrees with the table; the surgeon should then place the middle part of the sole of the patient's foot against the front of his chest just below the clavicle, and supporting with both hands the lower ends of the bones of the leg, should use the whole strength of his shoulders to force the foot by a series of sudden jerks into the position of full calcaneus—a position in which it forms an acute angle with the leg.

One should be able to judge either in advance or else during the first stage of the correction whether the retraction of the tendo Achillis is such as to render necessary its elongation; if so, this should be done after correction of the varus, but before manipulation of the ankle joint.

3. The surgeon should never forget to manipulate the toes into good position, for the clawing of these, and especially of the great toe, constitutes a very considerable disability.

4. *Correction of deformity at the knee joint.*—Where in addition the knee joint is stiff in flexion it is essential that this deformity should at the same time be corrected, for its persistence would render useless all the energy expended in the manipulation of the foot.

In two cases, each with the knee stiff in flexion as well as the foot in equinus, I managed at two sittings, and without having to resort to tenotomy of the hamstrings, to obtain satisfactory correction of both deformities; at the first operation the foot was fully corrected and the knee but partially, and the whole limb immobilised in plaster right up to the pelvis; at the second, a month later, further correction of the position of the knee joint was effected, so that the end result in each case was a foot fixed in flexion and a knee joint fixed in almost complete extension. Both patients, formerly absolute cripples, are now able to walk perfectly well without even the assistance of a stick.

5. *The dressing and method of fixation.*—The short incision through which the tendo Achillis has been lengthened should first be dressed with aseptic gauze and then the limb covered with a layer of stockingette and the foot fixed in plaster in the position of calcaneovalgus. It is essential that the patient should be kept well under the anæsthetic, and also that the foot should be held firmly in position until the plaster has dried.

I usually make a plaster gutter splint that leaves the dorsum of the foot and the front of the ankle free to accommodate the swelling that invariably takes place, and concerning which I shall have more to say in the next section.

6. *The after-treatment.*—After such manipulation there always occurs a considerable amount of inflammatory swelling and of bruising of the foot; for two or three days the pain is very severe and demands relief by morphia. Save, however, in the one rather exceptional case that I have referred to above, I have never seen infective inflammation and suppuration, as I have always taken good care that all my other cases have been well and soundly healed, and that for a very long time before I have consented to operate.

After the subsidence of the acute pain and swelling the foot should remain in the plaster for a month; during this time, however, daily manipulation of the toes should be considered a matter of the greatest importance, otherwise they will rapidly revert to their clawed condition.

At the end of the third week the patient should be made to walk about in the plaster, which may be specially thickened for that purpose with further layers of plaster bandage.

At the end of the fourth week the plaster should be removed and the patient encouraged to commence walking.

From this moment, however, special attention should be paid to the patient's re-education in walking. In such cases walking may have either the very best or the very worst influence; the best, where it is carried out properly, the sole flat on the ground; the worst, where it is accompanied by the least deviation of the foot into varus or equinus.

PART II

NON-ARTICULAR LESIONS

CHAPTER I

SCARS: LESIONS AND DISABILITIES OF MUSCLES

1. Scars

A scar may interfere with normal joint action in one of two possible ways: by directly involving a muscle and so affecting the efficiency of its contraction, or by forming a hard retractile fibrous band of variable depth that beyond a certain point completely arrests further movement of the joint in a given direction.

The involvement—in many cases of no great extent or depth—of a muscle in a scar is in most cases accompanied by a certain amount of atrophy and sclerosis of the rest of the muscular belly; but often this is very slight, so that the disability is largely the result of the adherent scar. Such a condition is easily recognised by the depression of the scar that takes place when the muscle contracts. In cases where the perfect functioning of the muscle is physiologically important, as it is especially in the muscles of the forearm, excision of the scar followed by suture of the wound is certainly indicated, and usually gives very satisfactory results.

The second of the two conditions that interfere with joint action is the existence near the joint of a large dense mass of scar tissue replacing the soft parts that have been destroyed over a variable extent and depth. In civil life such a condition is not infrequently the result of a severe burn that has destroyed the skin and subcutaneous tissues of the neck, of the anterior wall of the axilla, or of the flexor folds of the elbow, of the hip, of the knee, or of the fingers. In the one direction the movement of the affected joints remains quite free; beyond a certain point all movement in the opposite direction is, however, prevented by the band of scar tissue, the gradual retraction of which, moreover, tends always to draw the limb into a position more or less abnormal or disabling. Here again excision of the scar tissue, followed by skin grafting or some other plastic operation, is indicated, and gives excellent results.

The burns met with in war surgery—which are not at all rare—should be treated along the same lines. I have not seen in soldiers, however, any of such enormous scars as result in civil life from vitriol burns, or in children from their clothes catching fire or from their grasping a red-hot iron bar.

In war surgery the principle of the operation is the same, although, especially in the regions of the body just indicated, its performance is much more difficult when the scars resulting from the prolonged suppuration of extensive war wounds are large and deep. All around the mass of scar tissue—which, indeed, in part represents them—the muscles are sclerosed and retracted; whilst very often vessels and nerves are surrounded and involved. Because of recrudescence of activity on the part of germs that have remained dormant over long periods in the islands of scar tissue, healing by primary union not infrequently fails.

As in the case of the scars that result from burns, one should never be in a hurry to operate; for, as every one knows, scar tissue in time—usually a matter of months—gradually becomes softer and more yielding, so that, provided that there is no compression of nerve and vessels, one should always wait to see how far such improvement will go.

Where—and this occurs especially often in the case of the knee joint with a scar in the popliteal space—the contraction of the cicatricial mass pulls the joint into some permanent mal-position (flexion of the knee joint, permanent adduction of the arm), forcible correction of the deformity should be carried out only in slight cases, always in several stages, and then only with the greatest caution; one should always beware of tearing of the scar with rupture of the vessels enclosed with it.

Some have considered that the normal process of softening and progressive increase in suppleness of scar tissue can be hastened by means of such various physical agents as massage, ionisation, exposure to the X-rays and to radium. As regards this point it is difficult to form an accurate judgment, for before the war we hardly ever saw such extensive masses of scar tissue. But from my own personal experience—considerable of burns, though not of military cases—I am inclined to believe that the effect of such physical remedies is but slight. As the patients remain for many months attending a physiotherapeutic centre, it seems to me that the improvement attributed to these various agents is really due to time. Many of these cases would do better working at their homes than undergoing an occasional treatment with radium, and meantime wasting their time in idleness. I have, moreover, seen several cases of obstinate ulceration from radium burns; radium is inferior to the lance of Achilles, in that it cannot cure its own unfortunate effects.

2. Muscular Lesions and Disabilities

A. NOMENCLATURE. GENERAL CONSEQUENCES

(*a*) *Nomenclature.*—Conditions that interfere with muscular contraction are of two chief varieties:

(1) Lesions, the result of actual immediate involvement of the muscle in the initial trauma (*e.g.* the division or destruction of muscular bellies and of tendons), or its later involvement in the inflammatory or reparative process (*e.g.* sclerosis, retraction and adhesion of muscles).

(2) Muscular lesions that result secondarily from lesions of the vascular and nervous systems. I will give an example only of the vascular troubles; many patients in whom the main arterial trunk of a limb has been tied, especially in the case of the lower limb, develop a disability in the muscles of this limb; these become very easily fatigued, and the patient is of very little use for marching. Among muscular lesions secondary to injuries of the nervous system are to be included a certain form of atrophy plus contracture that is probably reflex in origin, contractures purely hysterical, and paralyses from division, anatomical or physiological, of nerve trunks.

(*b*) *General consequences.*—(1) The destruction or paralysis of a muscle or the division of its tendon results, in the first place, in abolition or loss of the active joint movement normally effected by its contraction.

(2) The second consequence, of very great importance to the surgeon, is the production of deformities the mechanism of which is very easily understood.

When a sclerosed muscle retracts or shortens it draws towards it the movable bony lever into which it is inserted ; a typical example is the production of an equinus position of the foot by retraction of the gastrocnemius and soleus (often called " shortening of the tendo Achillis "). A similar result occurs from the contracture of any muscle or group of muscles which comes to exert a permanent pull on the bony lever in the direction in which they normally act on it.

When all the muscles that normally move a joint are paralysed this joint hangs perfectly flail and inert ; there is no power of active movement in any direction. Where, however, only a certain number are paralysed, their unparalysed antagonists draw the bony lever in their direction, away from that of the paralysed muscles.

(3) Each of these individual lesions often co-exists with such ankylosis or stiffness of joints as we have studied in the earlier part of this book.

B. Direct Lesions of Muscles

Division of Muscle and Tendon ; Loss of Muscular Substance

1. There is nothing of special importance to add to the detailed classical description of the phenomena and treatment of cut tendons found in ordinary

text-books. Occurring in the fingers or at the wrist —the latter the commonest site—the diagnosis of this lesion usually presents no difficulties. Provided that suppuration is absent, and that there is no actual loss of substance, the indications for treatment are perfectly simple and clear, viz. the suture of the tendons, primary or secondary according to the circumstances of the case. In war surgery, however, these conditions of successful suture are not often realised. The frequent co-existence of lesions of the bones and joints, the almost constant presence of sepsis, and the occurrence of considerable loss of tissue all serve to render suture at the best inadvisable, at the worst quite impossible.

The extensor tendons are not infrequently divided in their entirety as they lie on the back of the carpus; this results in loss of all active extension of the fingers and wrist; and, as their distal ends soon become adherent and firmly fixed by scar tissue to the bone, there is a considerable interference with active and passive flexion of the wrist and fingers; hence a very serious disability ensues. In the majority of such cases the surgeon is perfectly justified in attempting direct suture where the cut ends can be brought together on hyper-extension of the wrist, or where this is impossible some form of tenoplasty or suture "at a distance"; the technique of these operations I need not describe. If they fail, nothing has been lost; if they succeed, much has been gained.

In the case of the tendons of the fingers secondary suture is but rarely feasible; I would refer the reader to what I have said as to the indications for amputation of the fingers in such lesions.

While dealing with the subject of cut tendons, I think it is worth while drawing attention to a disability that not infrequently results from cutting through the ligamentum patellæ in arthrotomy of the knee joint carried out through a U-shaped incision. Although healing by first intention ensues, occasionally the quadriceps extensor muscle is thrown more or less completely out of action. I do not wish to imply that on this account this operation should never be performed; sometimes it is quite an indispensable method for an adequate exploration of the knee joint. But I think that on this account alone it should not be allowed to develop into the method of choice or routine.[1]

2. Cases of transverse division of a muscle—which whenever healing has taken place with considerable separation of the ends should be treated by secondary suture—are often disabling quite as much by the atrophy and sclerosis of the fibres that remain intact as by the actual division of the others, and this even where there exists a solid block of scar tissue in the muscle. The extent of this disability should be remembered, and so the transverse division of muscle during operations avoided altogether, except in those very rare cases of absolute necessity or in late reparative surgery where the joint acted on is already ankylosed.

3. A laceration or gap in an aponeurosis through which protrudes a muscle hernia, even although quite narrow, constitutes a not uncommon cause of disability; particularly when it occurs in the leg or thigh, by failing to give proper support to the muscles it

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[1] Where the U-shaped incision is performed it is better to separate the tubercle of the tibia. In selected cases the longitudinal incision through the patella is called for.—Ed.

results in an inability to march, although it is quite possible that were peace declared at once a good part of this disability would very quickly disappear.[1]

I will remark in passing what seems to me very often overlooked, that muscle hernias protrude through the gap in the fascia not during contraction but during the stage of relaxation of the muscle.

A good number of these fascial rents and tears, for example, those of the calf, can be quite easily sutured. The fascia lata of the outer side of the thigh, and especially the deep aponeurotic fascia of the antero-external aspect of the leg, are usually, however, far too tense to allow of this, no matter how narrow the gap is ; in some of these closure has been quite successfully effected by means of fascial graft.

4. Loss of muscular substance with adherent scars occurs most commonly on both aspects of the forearm, over the antero-external aspect of the leg, and also over the posterior surface of the trunk. The loss of tissue represents that destroyed by the actual trauma as well as that subsequently lost from sloughing due to the virulence of the infection. In this connection I wish to issue a warning against the very free excision of wounds so often carried out to-day in the attempt to get rid of all infected and damaged tissue and so ensure primary union. I quite recognise that frequently most remarkable results are in this way obtained ; but in some cases consideration of future function should have their place, and persuade the surgeon to be less radical, to be content with a less brilliant immediate result, with a slower method of healing.

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[1] No disability occurs in cases where for plastic reasons fascia is removed.—Ed.

In the forearm and in the leg the usefulness of the muscular tissue above the level of the cicatricial mass is completely abolished, with the result—a greater or less degree of weakness or inertia of the joint below that is controlled by these muscles. In all cases the question arises, Is operation worth trying?

In the majority of cases it is not; after excision of the scar and freeing of the muscle ends the distance separating these will be found to be too great to allow of suture of the lower tendinous part to the upper fleshy muscular belly. I have seen cases of this sort, however, in which it was proposed to explore and free the main nerves of the limb—a perfectly useless and ridiculous procedure. One of such cases was that of a patient with non-union of the shaft of the radius a little above its middle and with extensive destruction of the flexor and some involvement of the extensor muscles of the forearm; liberation of the muscles having failed to improve the use of the hand, the surgeon actually proposed, after the lapse of a few months, to explore the nerves above the level of the lesion.

Now this constituted an error of diagnosis that is far from uncommon, although quite easy to avoid—that of mistaking loss of motor power from destruction of muscle for that of an actual paralysis. Such a mistake can be easily avoided by a careful examination of the sensibility and of the movements that can still be carried out below the scar, by looking for the presence of trophic and vascular disturbances, and especially by determining the exact level of the wound and its relation to the points of origin of the motor branches of the nerves to the muscles affected.

In the case of the patient to whom I have just alluded there existed below the scar no sign of any nerve involvement, and the scar itself was obviously well below the point of origin of the motor branches of the median and musculo-spiral nerves to these muscles. I have dealt with this point at length, because on many of the patients' labels I have noticed this obvious error of diagnosis. In these apparently the existence of a nerve lesion was all the more believed in because of the electrical reactions of the lower ends of the divided muscles; but of course the reaction of degeneration is to be expected in these lower ends, which, normally almost entirely tendinous, are now sclerosed and degenerated.

Whilst in these cases operations are of but little use, equally inefficacious as regards the actual muscle lesion are both mecanotherapy and physiotherapy. These are of use, however, in strengthening and training the muscles that have escaped destruction and in teaching the patient to make use of movements that in the case of the hand, however mediocre, are almost always better than those of an artificial hand. In this way can be appreciably shortened the time necessary for the functional adaptation and manual re-education of the patient. In the case of the foot, where in addition to loss of motor power is developed mal-position at one or more joints, the surgeon may be justified in performing late amputation.

In the trunk a certain number of cases of excision of the scar followed by muscle suture have given good results ;—for example, in the dorso-cervical region to prevent the head falling forward ; in the lumbo-sacral region to assist in the balancing of the body on the pelvis. The wearing of a spinal support or jacket is never of much use.

C. Sclerosis and Secondary Retraction of Muscles

1. Etiology.—There is no need to dwell at length on the sclerosis, often indeed combined with actual loss of substance, that results from the occurrence of suppuration, localised or diffuse, either in or between muscles. Such is met with in a greater or less degree in all regions of the body, and is often accompanied by sclerosis, compression or chronic inflammation of nerves and vessels, so that to the muscle disability are added vasomotor, trophic, and actual paralytic troubles as well.

Sclerosis may result, however, from mere contiguity of a muscle to a focus of but moderately intense inflammation; everyone is familiar, for example, with the torticollis from inflammation by contiguity of the sterno-mastoid muscle during mastoiditis, or an acute lymphadenitis of the deep cervical glands; such a slight superficial myositis may in exceptional cases be followed by a permanent extensive and severe sclerosis of this muscle.

Certain traumatic lesions that do not include an open wound may have a similar result. The very serious form of sclerosis of the flexors of the fingers that we occasionally meet with in cases of fracture of the lower end of the humerus, less commonly of the bones of the forearm, is an example of this.

This form of sclerosis is most commonly associated with a combination of very great swelling and ecchymosis of the forearm with tight splinting; marked œdema and cyanosis of the hand follow. In this condition, then, an important pathogenic rôle has been accorded to a local ischæmia from compression of the blood-vessels of the arm, from which is supposed to result a sort of aseptic necrosis, that in turn is followed by a sclerosis of the muscle fibres. This condition has been called ischæmic paralysis and ischæmic contracture; it is quite possible that it is of ischæmic origin, but it is certain that it is neither a paralysis (the result of a nerve lesion) nor a contracture (an exaggeration of the physiological condition of muscular contraction); it is primarily a retraction following sclerosis of muscle, although it possibly may in addition be associated with vascular and trophic disturbances due to simultaneous involvement in the ischæmic area of vessels and nerves.

A retraction of traumatic origin that is analogous to this ischæmic retraction may be localised to a single muscle, *e.g.* retraction of the sterno-mastoid muscle that occurs in obstetrical torticollis, to which a similar etiology and pathology have been attributed.

I know that the chief part in its production has been attributed by some pathologists to congenital syphilis; and it is possible that such may play a part of secondary importance in the etiology, although probably not constantly; if the primary factor in its production be not mechanical, the sclerosis resulting from interstitial rupture of muscle fibres with the formation of a hæmatoma—and this explains the muscular swelling,—how can its frequence in breech presentations, and the predominance of the lesion on the right side, be explained? One may invoke at will a constitutional condition like syphilis (and why not in other cases of post-traumatic sclerosis of muscle?), without which the local injury and hæmatoma might possibly not result in the muscle sclerosis and retraction, but one cannot deny the role of the original trauma.

Again, during the war we have seen a condition of atrophy combined with sclerosis and retraction extend throughout the whole belly of a muscle that has been simply penetrated by a bullet, the track of which has healed in a few days without suppuration beneath the small scabs that mark its points of entrance and exit.

The cause of this seems to me to lie in the considerable force of the concussion imparted by the projectile to the muscle, which immediately becomes extensively infiltrated with blood. This seems to be the more likely from the constant occurrence of swelling and ecchymosis over the whole of the calf following its penetration by a bullet—a penetration which at first appears to have inflicted but very slight damage. Moreover, all surgeons who have operated on recent wounds, whether infected or not, have been struck by the distance from the actual track of the projectile that this infiltration of blood, this contusion of muscles and of intermuscular connective tissue, extends.

The occurrence of this extensive sclerosis and retraction of muscle in such apparently simple wounds, whether its cause be analogous to that of obstetrical torticollis or to that of Volkmann's contracture, need not, then, astonish us. In actual fact, the whole muscular mass has been broken up by interstitial rupture and effusion of blood ; it undergoes degeneration, atrophies to one half its former volume, and retracts. The most marked example of this phenomenon is to be seen clinically after penetration of the muscular bellies of the biceps and of the gastrocnemius. On the other hand, such a train of events occurring on a limited scale in a muscle like the quadriceps extensor, or a deeply-placed muscle, will very easily be overlooked. Probably for the same reason such conditions have not been noticed in connection with the muscle injuries of civil life, because, like the initial effusion of blood, the process of sclerosis and retraction affects but a limited extent of the muscle; hence a degree of atrophy that is but slight and localised, and of retraction that the antagonistic muscles have no difficulty in successfully resisting.

2. **Mechanical Consequences.**—Sclerosis and retraction of muscles give rise to two different orders of mechanical consequences:—

1. A loss or weakening of the muscular action that is proportional to the extent of the damage inflicted on the muscle fibres. This needs no explanation or elaboration.

2. A shortening of the affected muscles that results in a permanent approximation of their points of origin and insertion; in other words, in a permanent deviation of the corresponding mobile lever of the joint into which they are inserted in the direction of the normal pull of their contraction. Such deviation is the result of retraction and not of contracture.

Since this deviation is the result of a permanent shortening of the affected muscle, there is thus produced a permanent characteristic attitude of the joint, provided always, of course, that its range of movement is not otherwise restricted by stiffness or ankylosis; and such attitude will become exaggerated whenever the shortened muscle is subjected to tension, *e.g.* by attempting forcibly to separate its points of origin and insertion by some passive manipulation of the joint next above.

For example, retraction of the flexors of the fingers results in flexion of these digits whenever the wrist is brought into a straight line with the forearm ; such flexion becomes exaggerated, however, as soon as the wrist is extended ; on the other hand, flexion of the wrist, which means an approximation of the points of origin and insertion of the flexor muscles, allows of passive, if not of active, extension of the fingers.

Similarly, when the calf muscles are shortened, flexion of the knee relaxes the tension on them, so that partial, if not full, correction of the equinus position of the foot becomes temporarily possible.

When, on the other hand, an attempt be made to correct the fixed position of the foot with the knee held in extension, the shortened fibrous muscles will at once become taut and stretched, and will be felt to offer a definite, albeit elastic, resistance to the correcting force. I am, of course, here speaking only of cases uncomplicated by joint stiffness.

3. Preventive Treatment.—The slighter cases very often pass unnoticed. In them, as in secondary superficial myositis of the sterno-mastoid, the resumption of normal movements is sufficient to cure the condition, as the strength of contraction of the antagonists prevents retraction and shortening. In military cases such spontaneous cure quite frequently occurs, but there exists on the whole a greater tendency to retraction, which it becomes necessary to counteract by passive movement or by elastic traction, methods of treatment similar to those that I have described as indicated in cases of slight or commencing stiffness and deformity of joints.

In just the same way, the application of continuous extension in a case of inflammatory torticollis is very often effective in preventing permanent shortening of the muscle.

This preventive treatment when carried out by the surgeon with care and assisted by the collaboration of the patient in the adoption of some form of suitable " home mechanotherapy " will almost always succeed in preventing definite or severe retraction, and so in avoiding the necessity for operation.

4. **Surgical Treatment.**—The various forms of physiotherapy are powerless to remedy the loss of function of the fibres that have become sclerosed; carefully regulated exercises can improve the condition solely by increasing the strength of contraction of the muscular bundles that remain intact.

As regards the mal-position of the limb, as soon as the sclerotic process has come to an end this similarly becomes fixed, and all mechanical methods of correction will fail; too often such are persisted in when operation alone can effect the correction.

Retraction of the flexors of the forearm has been treated by two different operative procedures:

1. The liberation of the muscles combined with tenoplasties, with the object of elongating the shortened muscles and of allowing them to work more smoothly.

2. Shortening of the two bones of the forearm by the removal by a cylinder from the shaft of each. This serves to give more play to the shortened muscles.[1]

Neither of these operations, however, has yielded very satisfactory results; in many cases no improvement whatever has followed. As, moreover, both procedures are both tedious and difficult, they have not been widely practised.[1]

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[1] M. Leriche showed at the Société de Chirurgie a case in which in order to increase relatively the length of the muscles he resected the lower half of the astragalus. I have never met with a case too bad to be cured by elongation of the tendo Achillis.

On the other hand, in the retraction of single muscles excellent results are given by tenotomy; at least in the case of the gastrocnemius, for the results of tenotomy of the biceps cubiti are not quite so good. Fortunately it is but rarely indicated in the case of this muscle, possibly because of the extending influence of the weight of the arm, at any rate in those cases in which the use of an arm sling has been prohibited.

Retraction of the gastrocnemius and of the soleus, although these muscles are in reality both extensors and adductors (see page 58), results in the production of a simple equinus position uncomplicated by any varus deformity; the mechanical consequences of this have been studied on page 66. Such a condition should never be treated by a surgical appliance or boot (see page 68), but always by tenotomy of the tendo Achillis.

The simplest method of performing this operation —as it is the original method—consists in mere transverse division of the tendon; this is very easily carried out in accordance with the technique sufficiently well described in elementary text-books of operative surgery; it is unnecessary to repeat it here.

After division of the tendon the foot should be forced well into flexion (to ensure a good result the foot should form an acute angle with the leg) so that the heel descends carrying with it the lower end of the cut tendon, which thus becomes separated from the upper; a separation of from 7 to 8 centimetres can in this way be effected. The foot should then be fixed in plaster in this position so that a cicatricial band comes to form within the tendon sheath, which so reunites the two ends of the cut tendon.

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[1] In the treatment of this condition I would refer the reader to another procedure which gives much better results than operation. The wrist should be fully flexed, so that the fingers become comparatively relaxed. Separate splints should be applied to the fingers, and by degrees the metacarpo-phalangeal joints should be extended and a splint placed from the wrist joint to the tips of the fingers. After the hand is straightened the splint is used to gradually extend the hand upon the wrist until dorsiflexion is complete. The structures are in this way made to yield in the direct order of their tension. The wrist should be dorsiflexed for a considerable time.—Ed.

By performing the operation on these simple, though classical, lines the following advantages are supposed to accrue:

(*a*) The whole operation can be performed subcutaneously.

(*b*) Local anæsthesia alone is necessary.

I must confess that the first of these advantages does not in the least appeal to me; I do not consider that in this region where the presence of a scar is of no importance whatever there is anything to be gained by making the operation a strictly subcutaneous procedure. As there is no danger whatever from infection, I have always, in hundreds of cases of congenital talipes, exposed the tendon by a median longitudinal incision, and in this way have always made certain that I have completely divided the tendon.

Elongation of the tendon, of which I am going in a few moments to give an account, can also be easily performed under local anæsthesia, and in many cases I have so performed it. In most cases, however, except in the presence of some special medical indication or by special request of the patient, I prefer a general anæsthetic; and this for reasons that I will give further on in this chapter, but reasons that apply equally to the case of simple tenotomy. I do not for one moment believe that the persistence under local anæsthesia of any degree of contracture that may be superadded to the retraction is of any value in indicating to the surgeon when he has divided a sufficient amount of the tendon to correct the shortening due both to the contracture and to the retraction. Operate always by the open method ; always cut the tendon completely through, and where its sheath is adherent to it cut that too, and you will invariably find that you have divided just enough, neither too little nor too much.

But as against these two quite hypothetical advantages of simple tenotomy there is to be set a definite disadvantage—the possibility of failure of union between the ends of the cut tendon ; this results in the development of a very disabling calcaneous deformity. It is impossible to specify with any certainty in what percentage of cases this occurs ; since I have never seen it follow simple tenotomy for congenital talipes in children, I am inclined to believe that it is quite exceptional, and that it occurs only in cases in which very wide separation of the ends of the cut tendon has taken place. I believe, moreover, that the likelihood of its occurrence can be minimised by operating well away from the insertion of the tendon, well above the heel. The fact remains, however, that at the Grand Palais we meet from time to time with cases in which it has occurred, and in which it certainly cannot be attributed to the occurrence of sepsis.

Now, in elongation of the tendo Achillis we have an operation almost as easy to perform, and one, moreover, which can never result in failure of union.

A very simple method of its elongation consists in dividing the tendon obliquely so that the lower end, descending along with the heel, retains at the same time through its tapering point contact with the upper end; the elongation in such a case being not equal to the distance between the points of entrance and exit of the knife on the opposite borders of the tendon.

This method, however—especially if a considerable amount of elongation is required—entails some risk that the reconstituted tendon will lack sufficient thickness and strength. But by a slight modification it is very easy to ensure a thickness one-half of that of the original tendon; this is quite sufficient for all practical purposes.

If the whole thickness of the tendon, instead of being cut obliquely, be split down the middle line over a length of six to seven centimetres, and if at each end of this incision the opposite halves of the thickness of the tendon be cut transversely, the whole incision being thus Z-shaped, there will be fashioned out of this length of the tendon two rectangular flaps, the lower of which will, when the foot is flexed, slide on the upper. The thickness at the seat of union of these two flaps will remain that of the original tendon; above and below this for some distance the tendon will be but half of this thickness.

As after oblique division, the edges that remain in contact may be sutured together; if there be but one centimetre of overlapping, this is not worth while.

As a matter of fact, as Delbet first showed me, one can in most cases, by omitting the vertical incision, arrange a more natural means of maintaining the surfaces in contact; after making the two semi-divisions of the thickness of the tendon, and on forcibly flexing the foot, the length of tendon between the two incisions will be seen to split into two halves that glide on each other, one upwards, the other downwards with the heel.

The only restriction which I would propose to the use of this excellent method—which indeed I have myself adopted—is in connection with cases in which there co-exists however slight stiffness of the ankle-joint.

In such cases the tendon will often be found to be red in colour, rough, and surrounded by thickened and vascularised connective tissue. Under these circumstances the cleavage of the tendon will probably require the application of a force greater than can usually be brought to bear. In the first case of this kind that I met, trusting in the usual way to the force of the correction to split the tendon, I succeeded instead in tearing it away from its insertion. The final result was good, the tendon re-attaching itself; but it is quite conceivable that it might have failed to do so, so that in other cases of this type I have always taken the precaution to split the tendon myself before flexing the foot; this has, of course, no real disadvantage except that the result does not look so neat.

Cases of this type are, moreover, far from rare; and as correction of the deformity takes great force, and as, moreover, the condition of the tendon cannot be foreseen, I prefer, except in special circumstances, to have the patient under a general anæsthetic.

After correction of the deformity, the foot, being brought to a right angle with the leg—except, indeed, where this is impossible on account of some bony deformity,—should be fixed in plaster for three weeks; during the last week, however, the patient may be allowed to walk about in the plaster.

At the end of the three weeks, when the plaster has been cut off and the stitches removed, in the great majority of cases the patient will be able to walk about at once in an ordinary comfortable boot.

A night shoe should, however, be worn for a further two or three weeks, preferably one with elastic traction so arranged as to keep the foot well flexed ; several times a day the patient should perform exercises to increase and maintain the range of this flexion ; and a certain amount of re-education in walking will be advisable, care being taken that during walking the sole, and especially the heel, is brought into normal contact and relation with the ground (see p. 62 and p. 106).

D. Contractures

Nerve lesions may result in abnormalities of joint position in two different ways : (1) by causing paralysis, (2) by causing contracture of muscles. The occurrence of either of these conditions, paralysis or contracture of muscles, will interfere with the normal equilibrium of the muscles controlling the joint ; thus in paralysis the unparalysed antagonists find their action unopposed, whilst the mere existence of contracture of course implies an exaggeration of the normal action of the affected muscles.

In both cases the predominant muscles draw the bony lever of the adjacent joint into which they are inserted in the direction of the pull of their normal contraction. Such deviations from the normal position occur especially in the hand and in the foot ; those of the foot have a very special interest to the orthopædic surgeon.

A permanent deviation or mal-position—which, however, in the case of paralysis is not of constant occurrence—having become established, the general indications for treatment are identical with those that obtain in all cases of club-foot, and may be summed up in the two phrases: "correct the deformity," "maintain the corrected position." The treatment of these cases of club-foot by contracture differs, however, at any rate in one important particular, from that of most other varieties of club-foot, in that in typical cases the chief difficulty consists not in the correction of the deformity but in the maintenance of the corrected position. In other words, despite the correction of the abnormal position the disturbance of muscular equilibrium still exists; hence arise in these cases certain indications for treatment by external appliance or by surgical operation, and between these two alternative methods of fulfilment of these indications the surgeon has to choose.

Both in cases of paralysis and of contracture it often becomes necessary, after correction of the deformity, to fix the joint by means of a special operation, that of arthrodesis, which is in reality the production by surgical means of an artificial ankylosis in good position.

A. Simple Contracture and Organic Contracture

True contracture is nothing but a condition of permanent contraction without the occurrence of any organic pathological change in the muscle fibres. Such is seen in its typical form, though associated with exaggerated reflexes, in an organic lesion of the central nervous system with degeneration of the pyramidal tracts, and also in purely psychic or functional disorders in which no organic change can be detected either in the muscle itself or in the nervous system.

What is the nature of this psychic condition ? It is difficult to define, for it is impossible to draw a clear and definite distinction between true hysteria, to-day known as pithiatism, which seems to be a genuine disease, and actual simulation. But the fact, now recognised, that Babinski has been insisting on for several years, is that hysteria is not the great "simulator of disease" that formerly it was considered. It is quite incapable of setting up organic changes in the tissues. Contractures, paralyses, stigmata are all purely psychic in origin, the result of suggestion ; all are capable on the institution of counter-suggestion of disappearing without leaving any traces.

Hysterical contractures, with which alone in this chapter we are concerned, are distinguished by being unaccompanied by either muscular atrophy or by modification of the deep reflexes ; they disappear under anæsthesia and during sleep ; whilst, on the other hand, they are often accompanied by other hysterical manifestations.

Such purely pithiatic contractures, resulting in the adoption of positions that are often most bizarre, are very frequent among the wounded, whether as the result of a definite localised wound of a general concussion or of some trauma of indefinite nature.

These cases are to be contrasted with other cases, in which in their most characteristic form the contracture is accompanied both by muscular atrophy and by exaggeration of the deep reflexes.

At first sight the general resemblance between these two classes of cases is very great, and our predecessors would have had no hesitation in labelling those of this second class hysteria as well as those of the first.

For cases of this class are often hysterical; and even if not malingerers, are often men who are not afraid to exaggerate their disability, to make use of, indeed to abuse it. This class of case was but rarely met with before the war, and then only in industrial accidents. To-day they are of frequent occurrence —these cases of contracture that undoubtedly in the first place was associated with an organic lesion, a sprain or a slight wound, but that persists for months or years after this is cured or healed, that is only too likely to persist until the end of the war.

Why this difference between civil and military cases? Probably because these slight primary lesions passed unnoticed so long as the patient had no interest in their exploitation, and because present circumstances have created such an interest.

The occurrence of muscular atrophy in connection with joint lesions has long been known and well recognised. A sprain of the knee joint at once results in a perceptible softening in the quadriceps muscle, and its wasting becomes obvious in the course of a few days. Whilst so perfectly obvious and easily perceptible in the case of large and superficial muscles and joints, such wasting is probably of constant occurrence in all joint lesions, varying, however, in degree according to the nature and severity of the lesion, and also, by the working of factors so far unknown to us, according to the particular joint affected. This muscular atrophy is a most important element in the functional disability of such inflammation or injuries of joints; and if I do not deal with it at length in this book, it is because its occurrence is well known and the importance of its treatment so well understood.

It has been definitely proved that the wasting is due to the joint condition and not to any immobilisation of the limb; after much clinical and experimental investigation the theory of its reflex origin has become pretty well established. This, however, has not deterred certain surgeons from taking the opposite view and persisting in regarding it as the result of immobilisation; hence they refuse to immobilise inflamed and injured joints. They sin through ignorance, for we know that the atrophy is reflex; moreover, as is to be expected, their results are for the most part deplorable. It is well to draw attention to these facts whenever opportunity occurs, for if we judge by the great numbers of cases of joint lesions (without wounds) that are being treated by mechanical methods in the physiotherapy centres, it would seem that this false doctrine and pernicious practice are gaining ground. In the first place, such cases should never be sent to such centres; and in the second, they should never be kept there. Immobilisation, it is true, results in a certain amount of atrophy; any wasting from this cause, however, is soon and easily made good as soon as active movement is resumed, whilst wasting of reflex origin is very much more resistant to time and treatment.

This reflex atrophy certainly occurs in its most characteristic form after joint injuries, but it would be a mistake to regard it as occurring only in association with such lesions. It is most probable that in a somewhat less marked degree it occurs in fractures, and even possibly after any form of injury whatever. I well remember reading twenty years ago some very interesting observations recorded by Klippel and his pupil, Daniel of Achardon, of the occurrence of atrophy after injuries, and especially after certain burns in childhood, in which a true arrest of development became more and more evident on comparison with the sound side. There is no reason, however, why such atrophy should take place only in children.

As a matter of fact, putting on one side cases of direct injury of muscle either from the initial trauma or from the resultant suppuration, we have all been struck by the frequency and the extent of the atrophy that has occurred even in the absence of any bone or joint lesion.

When associated, then, with muscular atrophy—its existence is always a point that can easily be verified—we cannot attribute to hysteria pure and simple any contracture that may be present in any part of the body. We return, then, to the subject of contractures. Such are often associated with an exaggerated state of the deep reflexes that may in some cases give rise to an epileptoid clonus—a similar clonus is quite common in certain amputation stumps ; this variety of contracture, then, is something new, something with which before the war we were quite unfamiliar. It is very probable that it, like the atrophy, is of a reflex origin. The associated atrophy may be slight and hence easily missed, but it is in my opinion constant in these cases which it is most essential should be clearly distinguished from cases of hysteria if they are to be successfully treated. For though there certainly does exist in these cases a psychopathic element, it is no less true that there is also a definite material organic lesion against which treatment by suggestion is as powerless as the coercive treatment that one would use with a malingerer.

This condition is in a way analogous to that in which an association of early hip-disease exists, with a general hysterical condition, and presents a symptom-complex exceedingly difficult to interpret; among all the local and general signs of hysterical hip it is not at all easy to detect or be sure of the slight signs of the genuine disease, and missing these means the institution of treatment that is all the more deplorable in its results because for a few weeks or months it seems to be effecting a cure.

Similar cases of contracture are to be observed associated with the aseptic encysting of tiny pieces of metal—a few millimetres in diameter—in muscles, tendons, ligaments, and in the articular ends of bones. I remember, for example, a patient with a small piece of shell—some 3 to 4 millimetres square—embedded in one of his femoral condyles near the articular cartilage, originating a spasm and contracture of the thigh muscles that held the knee fixed in extension. I removed it; the contracture ceased under the anæsthetic and never recurred. There was a certain amount of atrophy present, with some exaggeration of the tendon reflexes, an indication of the existence of a condition not purely or wholly psychic; nevertheless, there seemed to me to be some hysterical element in the case, so that I determined to make use of a certain amount of suggestion: for a fortnight I kept the knee flexed, with the heel against the buttock, in a starched bandage; at the end of that period the knee was left free, but not the slightest tendency to relapse ever appeared.

What exactly do we mean by this expression—neuropathic or psychopathic state ? Apart from its application to a certain definite, well-recognised class of case, it is largely no more than a mask for our ignorance. Each one of us has his own powers of toleration of physical pain and disability, of mental anguish and of fear ; each of us reacts differently to these disagreeable sensations ; and each one of us has a tendency to consider as neuropathic a neighbour whose physical sensibility is above the average or whose powers of endurance are below it.

What is important we should remember is that there exist certain cases of contracture not purely hysterical ; that on this account every case of contracture should be investigated with care, especially as regards the existence of atrophy, the state of the reflexes, and the presence of some slight, apparently insignificant focus of irritation. Where such a focus exists, whether in the form of a minute foreign body or of a small painful neuroma of a cutaneous nerve, treatment should commence by its surgical removal. The contracture should afterwards be treated directly, whether by general suggestive or by local physical or surgical means.

That in all cases non-operative treatment should first be given a serious trial no one will contest : massage, active and passive mobilisation, gymnastic exercises, and re-education of the muscles are all indicated ; and treatment by suggestion or by coercion should be utilised according to the seeming importance of the superadded psychic element judged to be present in each particular case.

But when these methods fail, as they not uncommonly do, it is quite wrong to persist with them for months and to forget that the deformity has originated in an organic lesion over which the patient has no control; and it is just in these cases that, despite what others have said about it, in my opinion, arise certain indications for surgical intervention that I wish to put before the reader.

Those contractures in which hysteria plays an important but not an exclusive rôle may affect any part of the body, may be of any degree of severity, may reproduce any deformity from scoliosis or kyphosis to a fixed flexion or extension of a single finger. They most commonly, however, affect the hand and the foot.

B. Club-foot from Contracture

I have never thought it wise to intervene surgically in a case of contracture of the hand, the various forms and shapes of which I will not here attempt to describe. I have thought fit, on the contrary, in a considerable number of cases of fixed equino-varus deformity, the result of contracture of the leg muscles, to perform various tenotomies and arthrodeses. For reasons I have already given, the subject of the causation and treatment of these contractures is a very difficult and obscure one, for in any case it is not clear—perhaps it never will be—what proportion of the deformity and disability is due to the general psychopathic state and what to the initial local lesion. But at any rate we are certain of the existence of both these factors, and this is of course the chief reason why the indications for surgical intervention are in so fluid and uncertain a state, and form so fruitful a source of discussion and controversy.

1. **Clinical Characteristics.**—At all centres of physiotherapy there are to be met numerous cases of contracture of the foot following a great variety of different wounds and injuries of the lower limb. Most frequently the original lesion has been a wound of the soft parts of the leg or of the foot; sometimes a mere subcutaneous injury, slight degree of trench foot, a sprain or a simple fracture; in other cases there has been a flesh wound of the thigh; in a few merely a slight and insignificant contusion.

The various fixed positions and attitudes assumed by the foot and the toes in these cases are very numerous; nothing could be more erratic than the distribution of the contracture among the various muscle groups of the foot and leg. Most numerous are the cases with the foot in equino-varus, the result of a combined contracture of the tendo Achillis and the two tibial muscles; with the foot in complete internal rotation, unaccompanied, however, by any true adduction at the mid-tarsal joint, so that during walking the whole outer border of the foot alone comes into contact with the ground; with the great toe either permanently flexed or permanently extended. In addition, contracture with the foot in any of these positions may be associated with contracture of the knee either in flexion or in extension.

Very often there is complete loss of power of voluntary correction of the deformity. The patient will sit with his foot on the ground in front of him and simply exhaust himself in vain efforts to move it on the leg; yet during these efforts quite distinct hardening and contraction of the leg muscles will be appreciable to the observer. In many cases all this expenditure of energy will result in no more than a slight flicker of the toes, suggesting, if not definitely proving, that the immobility of the foot is due not to any actual paralysis or paresis of the muscles of the leg, but to the irresistible fixed tonic contraction of the antagonists.

Voluntary contraction is, however, occasionally possible. I remember one case of severe equino-varus following prolonged exposure of the foot to cold, in which voluntary correction was effected by a very curious series of contortions of the foot. The patient, seated with his leg stretched out in front of him, first contracted his tibialis anticus so that its tendon could be seen standing out in marked relief; this of course produced complete inversion of the whole foot, the sole becoming vertical and looking inwards, and the formerly existing equinus and varus for the time completely disappearing. Then commenced rotation of the whole foot around its long axis in the opposite direction, so that the sole again became horizontal; in the meantime the tibialis anticus was of course relaxed. These movements were executed slowly but steadily, and continuously without any clonus. After maintaining the corrected position for some seconds the foot dropped again into the original position of equino-varus.

In some cases the foot maintains a perfectly normal attitude whilst the patient is standing, but develops a varus position immediately he commences to walk.

In a few cases he can passively correct the deformity himself with his hand. In most cases, however, it is the surgeon who has to perform the correction; this can often be effected by distracting the patient's attention, and then suddenly and unexpectedly seizing the foot and wrenching it forcibly into normal position. I believe that when this manœuvre fails it is because the surgeon has attempted the hopeless task of attempting a steady, continuous pull against the contracture instead of subjecting the foot to a sudden jerk. In so doing the surgeon will usually become acutely conscious that he is dealing with an actual contracture, for the tendons of the affected muscles will be felt to be acting with great strength against him, although executing at the same time a series of clonic contractions.

When one does not succeed in obtaining full correction the sensation is that of being stopped by something elastic, something that shows a tendency to alternate yielding and contracting, and not by a permanent fixed obstacle in the shape of a retracted muscle or of an organically stiff joint.

These cases of contracture are characterised, too, by the absence of any lesion of the bones and joints or of the soft parts ; there are, however, a few exceptional cases that I will refer to later in this chapter, in which is present a scar on the sole of the foot.

Another peculiarity of these cases of contracture of the foot is that the skin of the foot shows none of those callosities over points of abnormal pressure that are so characteristic of all cases of genuine club-foot. There can be little doubt that this indicates that the position of the foot is not nearly so fixed as one is at first inclined to believe ; the foot almost certainly relaxes to a more normal position during sleep, although this is not a point easily verified ; quite possibly, too, a certain amount of correction takes place inside the boot during walking, although this again is not easy to detect. In any case this is certainly a peculiarity of these cases that should be carefully borne in mind.

Because of the characteristic syndrome thus presented by these cases there but rarely arises any difficulty in differentiating them from cases of muscular retraction or of real joint stiffness; it is hardly ever necessary to have recourse to an anæsthetic. Such of course provides a certain method of diagnosis, but it has the disadvantage that its usual failure to cure the condition very often serves the patient with a pretext for refusing any genuine operative treatment that may afterwards be considered advisable.

So far, then, we have had no difficulty in recognising the condition as one of contracture; it is in connection with the nature and origin of this contracture that difficulties at once arise.

In many cases the most exhaustive and meticulously accurate examination fails to detect any sign of organic lesion or change whatever; these are cases, then, of undoubted hysteria, neuro-mimesis or pithiatism, whatever term the reader prefers. Such cases are now but rarely met with in the centres of physiotherapy; they are quite common of course in the neurological centres.

In these cases the contracture is purely psychic in origin; consciously or unconsciously the will persists in impressing on the limb an attitude that no doubt in some cases had at first some temporary local justification, in others none. Are any of these cases malingerers, or are they all genuinely pithiatic? This leads to the threshold of a very obscure problem, for if there exist cases perfectly characteristic of either class, in which the diagnosis presents no difficulties, there also exists between these two extremes a whole series of cases in which, because of our ignorance of what is normal and what abnormal psychology, because of our inability to draw a definite, precise line between what constitutes the working of the conscious and what that of the subconscious mind, we remain incapable of distinguishing the particularly expert malingerer from the patient who, through fear of again being wounded or further disabled, constantly maintains in some obscure corner of his brain a preference, unconfessed even to himself, for an indefinite sojourn in hospital to a return to duty in the trenches.

In many cases of club-foot by contracture, however, certain signs of organic change are well marked, especially atrophy of muscles and exaggeration of tendon reflexes. As regards the muscular atrophy, one might be inclined in those cases that have after correction of the deformity been fixed in plaster to attribute it to the immobilisation; but in many cases of marked atrophy there is no history of such fixation; moreover, the exaggeration of the tendon reflexes would not admit of any such explanation. Babinski has established a definite point of difference between these cases and those of pure hysterical contracture. On giving the patient an anæsthetic the contracture as well as the exaggerated reflexes is found to disappear only in the deepest stages of anæsthesia; both recur spasmodically as soon as correction of the deformity is attempted, and both constantly return before the patient again becomes conscious.

Are we here dealing with a reflex disorder comparable, as is generally held at the present time, to the amyotrophy that accompanies joint lesions? Is it necessary, especially in cases of contracture following frozen feet, to invoke the theory of an ascending neuritis? These questions can be asked, but as yet remain to be answered. All we can say is, that among the wounded there occur numerous cases in which, despite the fact that no nerve trunk has been injured, no muscle involved in suppuration, most remarkable and extensive atrophy of muscle co-exists with contracture and with marked exaggeration of myotatic irritability and of tendon reflexes, so great in some cases that the clonus is like that of an epileptic fit. In addition, in cases following exposure to cold the contracture is often accompanied by a remarkable cyanosis and coldness of the foot, that persists for months even during the heat of the summer.

One other factor in these cases, however, the importance of which cannot be denied, is the frequent association of a general psychopathic condition with the local physical or physiopathic disorder. This does not mean that a club-foot by contracture can be produced at will—for example, after a sprained ankle. It is impossible for any one to produce at will such a combination of atrophy and lack of tone in some muscles with contracture of others, the exaggeration of myotatic irritability and of tendon reflexes, and the general disturbance of the equilibrium among the different groups of muscles.

The deformity seems in some cases to be due to the persistence of a position that should under normal circumstances be but temporary, a position adopted in the first place for the relief or avoidance of pain.

In cases, for example, in which there exists a definitely tender scar on the sole of the foot it is but natural that the patient should commence to walk in calcaneus, in equinus, in varus, or in valgus, according as the scar is situated anteriorly, posteriorly, internally, or externally.

Under these circumstances the deformity can hardly be said to result in the first place from contracture, but from a voluntary contraction executed with the object of maintaining a certain definite attitude. In many of these cases, indeed, this attitude is not primarily the result even of muscular contraction, but rather of mere passive forces, the weight of the body acting down through an abducted or adducted leg resulting in a passive rotation inwards or outwards of the foot round its long axis. Such a position is, on account of the shape of the various articular surfaces and the points of insertion of the different muscles, one that is not easily realised by voluntary muscular contraction; by reason, however, of a certain amount of laxity of the lateral ligaments of the ankle and sub-astragaloid joints the passive force of the weight of the body acting through the foot against the ground can induce a considerable amount of such massive rotation of the posterior tarsus around its antero-posterior axis. Let the reader himself assume this position; during standing, the weight of the body will be found to maintain it; during walking, but a slight amount of muscular contraction will suffice to keep up the rotation during the period the foot is off the ground. As soon as the patient sits or lies down of course the passive force of the body weight ceases to act; but some additional factor seems to come into play, whether it be a reflex or some form of subconscious autosuggestion, which maintains the mal-position, and so in time leads to the production of a permanent club-foot; a result that cannot, I repeat, be explained wholly or satisfactorily by the theory of a mere persistence of a more or less naturally assumed position.

In other cases, where the deformity develops after a mere sprain or other form of slight local lesion, it takes origin probably from some similar set of circumstances, some more or less unconscious attempt to relieve or avoid pain, the patient instinctively commencing to walk on the outer border of the foot; in such cases, however, the deformity is more often equino-varus than pure varus. In some cases the contracture becomes complicated by the secondary development of retraction of muscles or of actual joint stiffness, but this happens less often than one might expect; I have seen cases of two years' standing without the slightest trace of such secondary lesions.

2. **Treatment.**—(*a*) *Psychotherapy.*—It is highly probable that no such cases would occur were there carried out always an efficient supervision of the position of the foot both during the period of the treatment of the original wound and also during the patient's first attempts to walk; were the least tendency to varus detected at once and corrected by careful re-education or by an appropriate alteration of the boot; were all incipient cases sent at once to special neurological centres for treatment by suggestion instead of being allowed to stagnate in the physiotherapeutic centres, where they simply become more and more possessed by the idea of their disability, where they have a bad influence on one another, and where, consciously or unconsciously, they come to imitate the various deformities and disabilities around them.

As a matter of fact all forms of physiotherapy are quite useless unless they are combined with or made a means of suggestive treatment, which alone is adequate in cases of pure pithiatism, and in such it almost always succeeds when properly used. Where there is an association of pithiatism with a local lesion that has resulted in a reflex contracture suggestion should also be regarded as the most important and essential part of the treatment. There is no doubt that in all cases of severe, old-standing contracture that have refused to react to all forms of mechanotherapy the general psychopathic element is almost always responsible for a considerable part in its production.

As regards the treatment of the contracture *qua* contracture, since all our classical methods of attacking it have so far failed, our latest methods as far as the indications for surgical intervention go are still tentative, still in the experimental stage.

(*b*) *Surgical treatment.*—Of course everyone commenced treating these cases along the traditional lines—correction under an anæsthetic, followed by two or three months' immobilisation in plaster.

It is necessary to insist at the outset that whenever in these cases an operation is performed it should always be followed by a course of suggestion and of physiotherapy, whereas treatment by these means before correction of the deformity would have been useless and sterile of results; with the foot in good position again they come to have a much more hopeful field of usefulness before them.

Everyone soon found out of course that relapse almost invariably occurred as soon as the plaster was removed. The cases in which after forcible correction relapse was apparently prevented by the wearing of an appliance with elastic traction were merely cases in which correction could have been equally effected by the use of such an appliance alone. It is the rule, moreover, in such cases for the patient after such relapse to refuse all further treatment.

The next development of surgical treatment consisted in trying the effect of correction plus tenotomy, particularly of the tendo Achillis and of the tibialis anticus; in this way it was hoped that when after the removal of the plaster the contracture recurred it would have nothing to act on, and so would lose its force. Even after this procedure, however, relapse is to be feared, although in my opinion its constancy or frequency has been considerably exaggerated. Among my own cases, by following up surgical treatment by well devised and carefully supervised mechanical treatment I have had excellent results by combining transplantation of the tibialis anticus with elongation of the tendo Achillis. As regards the elongation, I have already described its technique (see page 142); that of the tendon transplantation is as follows:

An incision of about 3 to 4 centimetres is made at the level of the ankle joint along the tendon—always prominent in these cases—of the anterior tibial muscle; this should on no account be carried downwards towards the sole. The tendon is next displayed and detached from its point of bony insertion by the point of the knife passed between it and the internal cuneiform bone. The end of the tendon is then caught in a pair of Kocher's forceps and pushed obliquely downwards and outwards between the tendon of the extensor proprius hallucis and the neck of the astragalus. In most cases it will remain and become fixed there without any need to suture it to the bone. Under these circumstances this muscle retains its flexor action, although this is weakened by shortening of the arm of the lever on which it acts, but loses completely its adductor action. I verified this very carefully, and it was clearly proved in two cases examined several weeks after the operation.[1]

In the slighter cases such a procedure will probably suffice, but I think it is wise in most to complete the operation by performing an arthrodesis of the calcaneo-cuboid and sub-astragaloid joints (see page 186). Such will by the time walking is recommenced effectually prevent any adduction of the fore-part of the foot, whatever traction be exerted on it by the tibialis posticus.

From the moment that the plaster is removed re-education in walking and careful mechanical treatment—both supervised by the surgeon who has operated—should be instituted; my practice is as follows:

The patient, his foot fixed in plaster in calcaneo-valgus, experiences great pain for two, sometimes for three days; to relieve this morphia is always necessary. He should remain in bed for a month, and for a fortnight after that should be made to walk about in the plaster.

At the end of this period the plaster is removed, the dressing changed, the stitches removed, and the patient encouraged to commence walking.

A comfortable boot with its sole raised along the outer border is always got ready in advance for the patient to wear as soon as he gets up; in addition to this general exercise of walking he is given regular daily exercises of flexion of all the joints of the lower limbs; when squatting with the heels together and the toes apart he inevitably flexes the ankle joint and tilts the os calcis into valgus.

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[1] The tibialis anticus is best transplanted to the base of the 5th metatarsal in those rare cases where such an operation is called for.—Ed.

The majority of the patients give no further trouble; they walk quite naturally at once, with the sole of the foot in contact with the ground. Some, however, whether through fear or habit, or because they have no desire to return to the trenches, still insist in walking not indeed in equinus or in varus but with the whole foot rotated inwards. This, however, is much more easily dealt with than true varus with flexion of the mid-tarsal joint; elevation of the outer part of the sole usually suffices to throw the foot into external rotation.

In addition, in such cases it seems to me to be wise to order a night shoe fitted with elastic traction to pull the foot into valgus and calcaneus, even in some cases to require the patient to walk in it for a few weeks.

All these details I see to myself; the patient does not escape to some department or centre over which I have no control. I have learned the necessity for this by experience. One of my patients—a very good patient, in whom I had obtained an excellent result—sent to a depot for the supply of an appliance came back to ask me why:

1. He had been told that, since the operation was incomplete, relapse was certain;

2. He had been treated by "mechanotherapy," with passive movements of flexion and circumduction of the foot.

He understood that the flexion exercises were all right, for I had explained to him, as indeed I do to all my patients, that the ankle joint remained intact and possessed a free range of movement ; but the circumduction disturbed him, for he had quite rightly understood that the object of the operation had been the complete suppression of this movement.

From that moment I have undertaken to fit these patients myself with a shoe, which costs 1 franc 50 centimes—a great saving to the State—and which is very light—of great benefit to the patient.

I have performed this operation sufficiently often, and I have studied its results in all cases after a sufficient lapse of time, to be justified in asserting that its functional results are good. There is no need to arthrodese the ankle joint ; the other joints remain firmly ankylosed ; it does not interfere in the least with walking, and it effectually prevents relapse of the deformity, so frequent after treatment by tenotomy. On return of the contracture it exhausts itself on an ankylosed joint, and so becomes ineffective.

E. Paralytic Deformities and Disabilities

Lesions of nerve trunks, whether partial or complete, anatomical or physiological, result among other things in paralysis, complete or incomplete, of those muscles whose motor nerves leave the trunk below the level of its lesion.

I do not intend here to deal with neurological surgery properly so called ; with the question of the possibility of correctly diagnosing the exact nature of the lesion ; nor with the special indications—which I suppose are always worked out in advance—for the performance of nerve suture, of neurolysis or of simple exploration of the nerve trunk; nor with the process and nature of regeneration. All these form the subject-matter of other special volumes of this series.

One aspect of regeneration, however, does very vitally affect us in this book. One knows that it eventually takes place; one knows, too, that even under the most favourable circumstances it is inevitably slow, that it is quite impossible in any case to indicate even approximately the time necessary for its accomplishment. The age of the patient, the extent of the damage or loss of substance sustained by the nerve trunk, the time that has elapsed between the reception of the wound and the performance of the operation, the distance to be traversed between the point of injury and the muscle to be re-supplied, are known to be some of the factors involved, but there is no constant relation between any of these and the actual period of regeneration.

Is it right to conclude in the absence of recovery of the least amount of voluntary movement long months after the performance of the operation that such an operation has been a failure? By no means, for during the whole long period occupied by the regeneration and growth of the new fibres no clinical sign of recovery is to be looked for, nor in the least expected. On the other hand, once the new fibres have succeeded in reaching their objective the whole phenomena of recovery may occupy but a relatively short period—a period sometimes to be measured in weeks. What is happening during the first of these periods—the period of regeneration—cannot be detected clinically nor by electrical examination; we remain completely in the dark until the commencement of the second period—the period of recovery. The onset of this second period is always sudden and without warning, and its duration correspondingly short.

It is important that the surgeon should realise this, otherwise he may be tempted under pretext of correcting a deformity or of reducing a disability to perform an operation that would forever render useless muscles that may for all he knows be within a little of complete recovery. I repeat, then, that the period of regeneration is not only long, but indefinite; we can at present fix no definite limit beyond which we can be certain that regeneration will not take place. This has a most important bearing on the treatment of paralytic club-foot.

The articular disability that results from division or compression of a nerve trunk differs according as all or only some of the muscles controlling the joint are paralysed.

In the former case the joint becomes completely inert, flail in all directions, moving in response to no law but that of gravity; in the latter, over-action of the unparalysed antagonists often results in the production of an abnormal and disabling joint attitude.

In the case of complete paralysis the joint is always at first, then, perfectly flail; the surgeon or patient can without any effort place it with the hand in any required position; when left to itself it simply falls back again into a position determined by its own weight. Such a joint may in time, however, become secondarily fixed in mal-position, either by the development of a bony deformity, the result of the persistent abnormal transmission of the body weight (the occurrence of even the slightest degree of this is rare in the adult), or by simple joint stiffness or muscular retraction (the occurrence of these is of course very frequent in war surgery); in either case the position of the joint becomes no longer capable of correction by simple manual force.

With the motor paralysis there co-exist in very many cases certain vasomotor and trophic disturbances; the existence of these should have an important influence in any consideration of the indications for surgical treatment. Fortunately, however, two of the most common of all peripheral nerve injuries, those of the musculo-spiral and of the external popliteal nerves, are associated with but very slight and unimportant disturbances of this sort. Along these two nerves, too, regeneration takes place more readily and more quickly than along any other of the peripheral nerves of the limbs.

The general principles of the treatment of such paralytic deformities and disabilities may be quite easily summarised as follows:

Where the joint is flail, the action of gravity should be overcome either by wearing an apparatus with elastic traction or by the performance of the operation of arthrodesis; this consists in such a removal of the articular cartilage as results in the production of an ankylosis of the joint.

Where certain muscles or groups of muscles remain unparalysed, treatment by tendon transplantation may supplant or supplement either of these two methods.

Where the joint is both deformed and fixed it becomes first of all necessary to correct this position, and after that to maintain the corrected position by one of the above-mentioned methods.

We will study the application of these general principles to three different individual cases: (*a*) circumflex paralysis or paralysis of the deltoid muscle; (*b*) musculo-spiral paralysis, resulting in wrist-drop; (*c*) great sciatic paralysis, resulting in either a completely flail foot or simply in a dropped foot.

Even in cases, however, in which one has good or fair grounds for anticipating the eventual occurrence of regeneration and recovery the patient should be fitted with supporting apparatus; this for the following reasons:

1. In order to avoid possible fixation of the joint in a disabling or deformed position;
2. In order to avoid stretching paralysed or recovering muscles;
3. In order to avoid the results of possible contracture or retraction of unparalysed antagonists.

(*a*) *Circumflex paralysis.*—Although I have not as yet in war cases had occasion to operate for paralysis of the deltoid, I will devote some space to its consideration, because in the rare cases in which it is complete and final and unaccompanied by any osteo-articular lesion it possesses a definite surgical indication. In such cases the disability is practically identical with that of the flail shoulders that follow resection; the weight of the limb, no longer taken by the deltoid, drags the humeral head down away from contact with the glenoid surface, and this in turn stretches and throws out of action the rotator muscles of the shoulder; and as apart from the deltoid the power of active abduction, direct or oblique, is nil, a fixed point of support for the movements of the forearm and hand is absolutely lacking. Such a condition constitutes a worse disability than ankylosis of the shoulder joint; indeed, often it forms a direct indication for the performance of arthrodesis of the shoulder joint. This should be carried out through an anterior incision identical with that for resection of the joint; through such it is a simple matter to remove the cartilage from the articular surfaces. I repeat that so far I have not had to perform this operation on a wounded soldier; but in cases of infantile paralysis, by its performance I have succeeded in obtaining for the patient both an efficient point of support for the forearm and a certain range of active abduction by rotation of the scapula. In order to regain such power of active abduction it is of course essential that the serratus magnus should not be paralysed.

Such a result is much better than that given by a mechanical appliance, which necessarily includes and interferes with the action of the elbow joint.

(*b*) *Musculo-spiral paralysis.*—A few words concerning this will suffice, for the opportunities that it provides for surgical intervention appear to me to be quite exceptional.

In musculo-spiral paralysis, when the forearm is pronated the hand falls into flexion; when, on the contrary, the forearm is supinated, the weight of the hand carries it back into line with the forearm. With the forearm pronated and the wrist flexed, the flexor muscles, their points of origin and insertion being thus approximated, are placed at a disadvantage, and so lose a considerable proportion of the strength of their contraction. In the opposite position of supination with extension of the wrist they regain the lost power; but it is precisely this position of supination with extension that in musculo-spiral paralysis the patient is unable actively to maintain. Stiffness of the wrist joint in flexion is rare in its occurrence.

Two different types of operation have been tried to remedy this disability :

1. Transplantation into the back of the wrist, or anastomosis with the extensor tendons of the tendon palmaris longus. I confess that I have always had but little faith in the results to be obtained by such transplantation operations, in which is completely reversed the normal function of the transplanted muscle ; for example, in this case a flexor is turned into an extensor.[1]

2. The performance of arthrodesis of the wrist joint, in a line with the forearm, or better, in slight extension. Where one is certain that regeneration will not take place this is certainly an effective way of ridding the patient of an external appliance. But one should refrain from stiffening the wrist as long as there is the slightest chance of recovery taking place.

In almost all cases, then, the patient should be advised to wear a prosthetic apparatus. Of these there are two chief types :

The original, that on which many of the modern patterns are modelled, is that of Duchenne of Boulogne. It consists of a cuff or sleeve for the forearm, to the back of which is attached the upper end of small springs, which are fixed below to small rings encircling the fingers. The second more modern type consists of a small anterior splint of the "cock up" shape, ending in a small palmar pad that serves to keep the wrist extended; this is much less cumbrous, lighter, and seems to serve its purpose quite as well. I may add that I have seen several patients with wrist-drop deliberately remove their apparatus before commencing their work; they are undoubtedly wrong to do so, but it at least suggests that they do not in every case find them of much practical use.

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[1] In the orthopædic centres in Great Britain we have found transplantation of tendons one of the most satisfactory operations, and, with a correct technique, very reliable. The palmaris longus unaided is not sufficient. We usually transplant the pronator radii teres into the extensors of the carpus, the flexores carpi radialis and ulnaris into the extensors of the thumb and fingers. The palmaris longus can be utilised for the thumb if preferred. The results of these operations are beyond question, and the patients require no apparatus when re-education is complete.—Ed.

Where there exists a tendency to fixation of the wrist in flexion or of the fingers, with thickening and adhesions of the extensor tendon sheaths, the dorsal apparatus of the Duchenne type becomes necessary. A similar form of appliance is useful to prevent or overcome retraction of the little and ring fingers in ulnar paralysis during the period of regeneration, or in cases where, without actual paralysis, retraction of these fingers is threatening to occur. Where, however, all chance of regeneration of the nerve has disappeared—and unfortunately failure of regeneration of the ulnar nerve is not rare—the wearing of such an apparatus permanently is really more disabling than useful.

(*c*) *Great sciatic paralysis.*—The great sciatic nerve or one of its branches is very frequently injured anywhere along its course from buttock to calf; the external popliteal nerve is, however, much more frequently injured than the internal. Not only is this so below the point of bifurcation of the great sciatic (it is here more exposed to injury by reason both of its nearness to the surface and of its intimate relation with the head of the fibula in fractures of which it is commonly involved), but in the main trunk of the nerve itself the fibres of this outer portion are much more frequently injured than are those of the inner part.

Hence we will concentrate our attention on the disability that results from division of the external popliteal nerve; the surgical problem presented by its paralysis is, moreover, simpler and less complicated than that of lesions of the internal popliteal nerve, in which in addition to the motor disability there exist circulatory and trophic troubles. We will study, then, the disability that results from complete division of the external popliteal nerve uncomplicated by any superadded joint stiffness.

Clinical study.—When this nerve is divided the following muscles are paralysed:

The tibialis anticus.—A strong flexor of the anterior tarsus; an adductor and internal rotator of the fore-part of the foot.

The extensores communis digitorum and proprius hallucis.—Both of which on completion of their action on the toes become feeble flexors and abductors of the foot.

The peroneus tertius.—A flexor and abductor of the foot.

Peronei longus et brevis.—Abductors; the longus in addition resulting in a lowering of the fore-part of the foot, and hence in an increase of the concavity of the internal arch of the foot.

The extensor brevis digitorum.

The unparalysed antagonists are:

The gastrocnemius and soleus.—Almost direct extensors of the ankle. These are the only muscles that act directly on the posterior tarsus.

The tibialis posticus.—An almost direct adductor of the fore-part of the foot.

The flexors of the toes.

All the short muscles of the sole of the foot.

Hence the foot, whether the patient be seated or recumbent, hangs down into a position of equinus, complicated by a certain amount of varus, with, in addition, slight flexion of the proximal phalanges of the toes. When the leg is shaken the foot dangles limply at its end.

Such attitude of equinus or equino-varus cannot be actively corrected by the patient; no active upward and outward movement of the foot at the ankle or mid-tarsal joints or upward movement of the toes at the metatarso-phalangeal joints is possible; the two distal phalanges of the toes can be weakly extended by the interossei. The opposite movements, on the other hand, can be actively executed, but result in an exaggeration of the mal-position of equinus (the increase in the deformity produced by their contraction is but slight, as the weight of the foot has already brought it well into equinus), in an increase of the amount of varus, and of the flexion of the toes.

Getting the patient to attempt all these movements singly and in turn is the only practically reliable method of determining which of the muscles of the leg remain unparalysed; in more cases than is often realised the case will be found to be atypical, not one of complete external popliteal paralysis, but of incomplete interruption by compression of the nerve by scar tissue, and very often complicated by a partial lesion of the internal popliteal nerve as well. It is now well recognised that of bullet wounds of the great nerve trunks of the limbs the majority are incomplete.

Although I have said that the fibres of the external popliteal nerve are the most exposed to injury, that is not meant to imply that the fibres of the internal always or altogether escape; these latter are often contused, torn, or compressed, so that a careful examination will show a symptom-complex indicating an incomplete lesion of both nerves, in which, however, the signs of external popliteal paralysis predominate. The same occurs in wounds of both nerves in the popliteal space. Lesions of the individual branches of the external popliteal nerve, of the anterior tibial, or of the musculo-cutaneous nerves are rare, and often difficult to distinguish from injuries and sclerosis of the corresponding muscular bellies.

Hence in all cases we should carefully investigate the two following points:

1. Whether there is complete paralysis of all the muscles supplied by the external popliteal nerve.
2. Whether there is any paralysis of muscles supplied by the internal popliteal nerve.

These points should be investigated by getting the patient to attempt in turn the particular action or movement normally performed by each muscle; not only should the actual movements of the foot be noted in response to the muscular contraction, but the tendon of each individual muscle should in addition be carefully palpated during its contraction; where two muscles perform the same action—for example, the two tibials are both adductors of the mid-tarsal joint—such palpation of the tendons singly and in turn becomes all the more indispensable.

The indications for surgical treatment.—The diagnosis having been established in detail, the indications for orthopædic treatment depend on:

1. Whether the deformity is a fixed one.
2. Whether, on standing, the sole of the foot comes into normal relation with the ground.

Indeed, the aim of all treatment of club-foot of whatever variety or origin may be said to consist of:

1. Full correction of the deformity; and
2. Maintenance of the corrected position so that the sole of the foot comes into normal contact with the ground during walking and standing. At the outset a "paralysed foot," which is not necessarily a "club-foot"—I will explain the difference later,—is a flail foot; in other words, it moves about, whether the patient be standing, walking, sitting, or lying, purely in passive obedience to the action of gravity and to the force of contraction of the unparalysed antagonist muscles; it dangles lifelessly at the end of the leg when this is shaken; from whatever position, it can always be passively brought to the normal without any effort of exertion being required.

Later it may become fixed in a position determined either by the contraction of the unparalysed muscles or simply by the action of gravity; such fixation is brought about by two factors acting singly or in combination:

1. A gradual deformation of bones and joints.
2. A retraction of muscles and ligaments.

In the case of club-foot the result of infantile paralysis, when the age of the patient allows of plastic modelling of the bones of the foot in accordance with new and abnormal lines of transmission of pressure, the former is a factor of the greatest importance. Certainly in such paralytic club-feet this adaptive process does not usually occur to anything like the same extent as it does in congenital club-feet;

but it is nevertheless always considerable. On the other hand, in such cases there is not so very great a tendency for the foot to be pulled by muscular action into varus and valgus ; such lateral deformity as exists, however, is always increased and exaggerated under the influence of the body weight during walking. In such cases, then, manual correction, even forcible, of the deformity is no longer possible ; a tarsectomy of greater or less extent becomes necessary before the bony obstacle is removed.

Such a state of affairs, however, is not to be expected in the case of the wounded ; they have passed the age when the bones are so exceedingly plastic. I have not as yet had to perform tarsectomy in any case of peripheral nerve injury in an adult. But in these cases the second factor, muscular and peri-articular retraction, becomes of very great importance. In addition to the paralysis, such peri-articular and muscular lesions develop as I have described at length already in this book ; and these become most marked in cases where the nerve lesion has resulted in vasomotor and trophic trouble.

Treatment will obviously, then, have to commence by dealing with these secondary lesions ; elongation of the tendo Achillis, followed by forcible correction of the position of the foot, will require to precede all other treatment. It will be equally obvious, however, that if treatment stops short at this, does no more than correct the deformity, relapse will almost certainly occur ; the disturbance of the muscular equilibrium still remains, and will tend to reproduce its former effect as soon as the plaster is removed from the foot.

Relapse, then, will occur in all but a few exceptional cases in which the original stiffness has been of severe degree and necessitated the exercise of great force in the breaking down of the dense adhesions, so that a severe and painful reaction with much swelling and bruising results; such cases are very likely to become permanently stiff in the corrected position, so that in them no further treatment aimed at the prevention of relapse will become necessary, provided always that the varus element of the deformity has been completely got rid of, that the sole during walking and standing can be brought into normal relation with the ground. Under such circumstances the occurrence of stiffness should be regarded as a favourable event. It would no doubt be quite an easy matter to perform the operation of arthrodesis in all cases that present the mechanical indications that I am going to recount; but the problem is complicated by the frequent lowered vitality of the tissues of the foot, so that it often becomes necessary to restrict all operative interference to a minimum of what is absolutely necessary and not of what may be merely desirable. Such cases constitute a test of the surgeon's clinical tact and experience, to decide when to perform arthrodesis and when to be content with manipulation into good position, followed by the use of a surgical appliance. As we shall see, a similar alternative lies before us in considering the treatment of perfectly flail joints.

The flail paralytic foot is that which drops inertly into mal-position merely through its own weight, but which can be passively redressed into good position without any effort.

In such, a very simple clinical examination suffices to determine what steps, if any, are necessary to maintain this good position. In order to decide this the patient should be examined lying down, standing, and walking; in this connection it should be borne in mind that a flail foot is not necessarily a club-foot.

A foot is to be regarded as a club-foot when the transmission of the body weight, active and passive, does not take place through the bony prominences of the sole in the manner described on page 61; when the foot is deviated either into valgus, the inner border of the foot transmitting the body weight along its whole length, the internal arch being flattened out by abduction and outward rotation of the fore-part of the foot, or into varus, the weight being transmitted through the outer border, the fore-part of the foot adducted and internally rotated. However, it is only the deviation into varus that concerns us here.

Now, in many of these cases, while the patient is standing at attention the sole of the foot retains a normal relation to the ground, since the slight inclination to valgus, due to the body weight acting on an arch already weakened by the paralysis of the anterior tibial and long peroneal muscles, counteracts any tendency to deviate into varus that may exist.

When, however, the patient commences to walk he always starts off with the paralysed foot, resting the whole of the body weight for the moment on the sound foot. By flexing the hip and the knee joints he lifts the foot from the ground, but at once, owing to the absence of all power of voluntary flexion of the ankle joint, it drops into equino-varus, so that when swung forwards the back of the toes are inclined to scrape along the ground. Whilst carrying the foot forward, then, the knee has to be sufficiently flexed to clear the toes from the ground; then by a sudden jerk it is again extended, so that the ankle joint through the inertia of the foot becomes passively flexed. By a rapid and skilful performance of this steppage manœuvre the patient eventually manages to get the heel into contact with the ground. If during this stage the leg has been abducted and externally rotated, the tendency will be for the sole to come into contact with the ground perfectly normally or in very slight valgus, any varus deviation being thus counteracted.

Such correction of the varus tendency, however, does not always take place; in a considerable number of cases this element in the deformity persists whilst the patient is walking.

In many cases, provided the boot worn is sufficiently light, this steppage manœuvre serves the patient well; but it is essential that the boot be light, for all extra weight seriously hampers the patient. Especially in cases where there persists the slightest amount of power in the antero-external muscles of the leg can walking thus be effected unassisted by the performance of arthrodesis or by the wearing of an apparatus. Where a tendency to varus exists, however, the outer border of the boot should be raised.

Where there is absolute paralysis with a perfectly flail foot, however, something has to be done to assist the passive flexion of the ankle joint, and the surgeon has to choose between a special boot and appliance and the performance of an open operation.

1. The principle of the surgical boot with artificial muscles is simple and very easily understood. Two elastic tractors (of indiarubber or metal springs) are fixed below, one to each side of the fore-part of the

sole of the boot, and above to a metallic upright fastened into the leg piece of the boot ; the higher this leg piece and metal support, the greater the force of traction on the foot exerted by the tractors. Where the two springs are of equal strength they result in direct flexion of the ankle joint. Any tendency to varus is corrected by (1) increasing the strength of the outer spring, and (2) by raising the outer border of the sole of the boot so that the foot is tilted into slight valgus. This thickening of the outer part of the sole from 5 to 10 millimetres, according to the case, should extend right along the boot, but should reach its maximum under the base of the 5th metatarsal bone. To effect this thickening the two layers of the sole should be unsewn and the thin wedge inserted between them and the whole resewn ; in this way the boot will be light and neat, and the wedge remains concealed.

2. *Arthrodesis.*—Permanent fixation is effected surgically by the performance of the operation of arthrodesis. This consists in a removal of the cartilage from the articular surfaces of a joint, which immobilised in good position undergoes ankylosis or synostosis.

In order to understand the indications for its performance in connection with the joints of the foot it is essential to have a full and accurate knowledge of the anatomy and physiology of these joints (see page 58).

If permanent correction of equinus be desired, the ankle joint must be arthrodesed at a right or, better, at an acute angle. If we wish permanently to do away with a varus deformity, arthrodesis of the midtarsal and sub-astragaloid joints must be performed, and the foot fixed in a position of slight valgus.

In the early days of the performance of arthrodesis the ankle joint alone was fixed; but it soon came to be recognised that mid-tarsal and sub-astragaloid fixation was necessary if all tendency to relapse of the varus was to be avoided.

Now, in these cases it is the varus and not the equinus that is the chief element in the disability.

Hence, nowadays, we find that in most cases all that is necessary is the fixation of the sub-astragaloid and mid-tarsal joints, the ankle joint being left freely movable; and this for the following reason:

Where the ankle joint is ankylosed in good position the patient walks as on a peg leg, on the heel alone. This no doubt is a gain where all the muscles below the knee are permanently paralysed; but where some retain voluntary power, however slight, where a certain range of but weak active movement of flexion and extension of the ankle be possible, a stiff ankle joint is no advantage, is indeed a disability.

In these circumstances the mid-tarsal joint should be fixed so that, all deviation of the fore-part of the foot into varus or valgus becoming impossible, the former adductors and abductors, whether they remain strong or paretic, develop into direct flexors and extensors of the ankle joint; the tendo Achillis loses, too, all its adductor action. Direct active flexion and extension of the ankle joint thus remains free.

As a matter of fact this form of arthrodesis is much better suited to cases of external popliteal paralysis than to cases of infantile paralysis. Of course the surgeon should never lose sight of the probability or possibility of the occurrence of regeneration and recovery of motor power, and also such arthrodesis should never be performed until all has been done in the way of neurolysis or nerve suture to favour the chances of such an occurrence. If and when recovery takes place, ankylosis of the mid-tarsal and of the sub-astragaloid joints will result in practically no disability at all, whereas ankylosis of the ankle joint would go very far towards rendering the whole laborious process of regeneration useless.

Most neurologists are agreed that it is quite impossible in any case of clinically complete division to decide by study of the signs and symptoms whether such division is anatomical or physiological, so that no indications for or against the performance of arthrodesis are to be gained from such a study.

The performance of arthrodesis of all these three joints in any one case is but very rarely indicated; this impossibility of foretelling definite failure of regeneration and recovery is the chief reason why I have always set myself against that procedure whereby the ankle joint is widely opened up, the astragalus temporarily dislocated, or even removed and replaced after a thorough stripping of its cartilage-covered surfaces; as also against those operations in which the skin and tendons in front of the ankle are cut across in order to give entrance to the ankle joint, even although they are subsequently re-sutured.

Such operations can of course lay claim to many successes; almost invariably, however, they end in ankylosis of the ankle joint, and absolute failures, and even catastrophes, are not infrequent. Only a few weeks ago a patient came to me with his foot blue, swollen, and fixed in varus, his toes powerless and retracted. There was nothing for the condition but disarticulation at the ankle joint—Syme's amputation—which I performed. He had been operated on some time previously by quite a distinguished young surgeon for arthrodesis of the joints of the foot; a transverse incision had been made, and the tendons in front of the ankle cut and re-sutured. From my examination of the foot after amputation, and also from the history, it was obvious that the resultant failure was not due to occurrence of sepsis; I found, however, the extensor tendons adherent and bound down to the bone by a dense cicatricial mass, whilst of the joints the sub-astragaloid alone was ankylosed.

From my own experience I know that arthrodesis of the foot can be carried out quite well through a short external incision; thus have I always performed it in children, and since the war in a fair number of adults.

Commence the incision at the anterior border of the external malleolus about 1 centimetre above its tip, and carry it down in a straight line to the most prominent part of the tubercle of the 5th metatarsal bone. This will be found to correspond to the upper edge of the tendon of the peroneus brevis. With the rugine now strip the ligaments and soft parts from the back of the tarsus, and also from the outer surface of the os calcis; this can easily be done without cutting any tendon. By the use of retractors you will now be able to make out one finger's breadth behind the tubercle of the 5th metatarsal bone the white line of the articular cartilage of the calcaneo-cuboid joint. Two or three blows with the mallet on a wide but narrow-edged chisel held perpendicular to the bones will suffice to remove the cartilage with a thin layer of bone from the two surfaces of the joint. There will then come into view the line of the astragalo-scaphoid joint, which you will treat in the same way, remembering that it occupies exactly the same transverse plane as the calcaneo-cuboid.

There is no need to spend much time in dealing with the anterior sub-astragaloid joint, for it is already opened into by removal of the head of the astragalus, the under surface of which resting on the sustentaculum tali constitutes the joint; a stroke or two with a sharp spoon will suffice to destroy what remains of its surfaces.

The posterior sub-astragaloid joint offers the greatest difficulty, as its surfaces are very close set; for this reason many surgeons hold that it cannot be effectively dealt with without temporary dislocation of the astragalus.

If, however, you force the foot well into varus and examine carefully just below the tip of the outer malleolus, you will be able to detect its slightly gaping joint space. This is narrow, but not too narrow to prevent you from removing the cartilage with a broad sharp gouge curved on the flat: Ducroquet has had a very suitable one made for the purpose. It is quite easy to do this even with an ordinary mallet and chisel, provided that it be remembered that the plane of the joint slopes backwards, inwards and upwards.

If in an exceptional case one has to ankylose the ankle joint as well, its capsule should be incised through the same incision, just in front of the fibula, and along its attachment to the front of the tibia; by retracting forwards the soft parts in front of the joint a sufficiently wide access is obtained to allow of the complete removal of the cartilage, either with a curette—starting with a small one—or with a hand gouge, or more simply with hammer and chisel.

Such a method of operating is not spectacular, but, as long as these details are carefully carried out, the desired end will be obtained without cutting any tendon or ligament of importance.[1]

Conclusion.—In any case of great sciatic paralysis, then, in addition to investigating and dealing with the state of the nerve itself it is of the utmost importance always, and as early as possible, to keep the foot in a good functional position.

In many cases no special treatment is necessary for this; the patient himself brings his sole into normal contact with the ground by the adoption of a "steppage" gait.

Where there exists, however, marked equinus, or the least tendency to varus, such should at once be corrected by the use of a special boot with a well-constructed sole, and fitted with elastic traction; this even in cases where one has good grounds for expecting successful regeneration and recovery. Under no circumstances should the patient be allowed to get about on crutches, his foot being allowed to deviate more and more into equino-varus, and to become increasingly stiff.

When the foot has become thus stiff, surgical intervention is necessary, but as long as the foot remains flail the indications and counter indications for surgical treatment should be carefully weighed.

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[1] In paralysis due to lesion of the external popliteal we have found tendon fixation reliable and simple, and it allows movement from the right angle upwards. The foot is held just a little above the right angle, and an incision is made in front of the tibia a couple of inches above the annular ligament. The tendon of the tibialis anticus is divided and passed through a tunnel in the bone. Through the same tunnel may be passed the peronei tendons, which are first divided, displaced, and passed through the annular ligament; or the peronei may be divided and passed through the fibula. The foot is then slung to above the right angle, and the patient is enabled to walk without an apparatus. In complete sciatic destruction the tendo Achillis is divided in addition, and the lower end fixed into the back of the tibia. We prefer this operation to that of arthrodesis.—ED.

So long as the foot can be passively redressed into good functional position, and so long as there is still hope of the eventual occurrence of recovery, a surgical boot with elastic traction should be adopted. In this connection the long period necessary for the accomplishment of regeneration, and the uncertainty of the signs of its progress, should not be left out of account.

In cases complicated by the least amount of varus, however, the situation is quite different ; a foot fixed in varus cannot adequately be controlled by a boot or appliance. In such cases the performance of arthrodesis of the sub-astragaloid and mid-tarsal joints permanently corrects the varus, and at the same time does not in the least interfere with the patient's powers of walking.

Arthrodesis of the ankle joint—with it, it is always necessary to combine arthrodesis of the other joints as well—is only exceptionally indicated ; it is to be performed only in cases with permanent paralysis of all the muscles below the knee. It is never indicated in cases of pure external popliteal paralysis ; whilst in complete division of the great sciatic or of the internal popliteal nerve, the occurrence of circulatory and trophic troubles render surgical intervention inadvisable.

CHAPTER II

LESIONS OF THE BONY LEVERS: DEFECTS OF BONY UNION

Cases of defective union and mal-union in bones are among the frequent after-effects of gunshot fractures. Loss of bony substance of immediate or later occurrence, wounds of the soft parts preventing the methodical application of requisite apparatus, infection of the bone of a more or less chronic nature, are among the causes of the frequency with which are observed:

1. Mal-union, the result of overlapping or angulation of fragments.
2. The excessive production of callus.
3. Delay and absence of union.

In the pages that follow I shall not deal at all with infective complications, with chronic osteomyelitis, but shall concern myself exclusively with the three lesions here enumerated, *i.e.* with the mechanical results, with the late motor disabilities, of such fractures.

1. Shortening and Angulation of Fragments

Fractures, wherever they occur, become consolidated:

(1) By means of a cylindrical sheath of sub-periosteal bone, rapidly formed, and destined eventually to be partially or wholly re-absorbed. This is the "provisional callus of Dupuytren."

(2) By the intermediate callus, which is lasting, and becomes organised gradually beneath the support of the sub-periosteal callus.

These two formations vary in their importance and persistence, according as the fracture is in a good or bad position, or is infected or uninfected.

Let us take as the first point of comparison the case of a simple fracture without any displacement, or with fully corrected displacement. The sub-periosteal sheath of small volume is re-absorbed rapidly, and only the intermediate callus persists. The bone attains, almost without perceptible difference, its former shape, length, and structure. When the reduction is imperfect, it is, on the other hand, the sub-periosteal callus which becomes the more important, at times very markedly so. Indeed, if the displacement persists, the detached periosteal laminæ undergo an intense ossification so as to make up what is lacking in the attempt at union of the badly displaced fragments.

In the case of a simple lateral displacement, fig. 2 shows how the periosteal callus firmly re-establishes the continuity of the bony lever; this then becomes modelled, but only to a slight extent re-absorbed; the consolidated bone remains with more or less sharp angulation and thickened, but without shortening.

The method is the same if overlapping exists, *i.e.* elevation of the lower fragment alongside the upper, to which it remains parallel (fig. 3). But the fractured surfaces here have lost all contact. Only the denuded surfaces of the shaft touch each other, without, however, giving support to the axis of the limb; hence the intermediate callus is slow in formation, and very slow in reaching strength sufficient to withstand pressure in the long axis of the limb; the callus is exuberant—it may end by being double the thick-

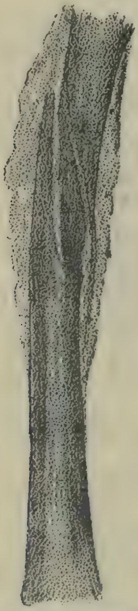


Fig. 1.—Sub-periosteal callus in a fractured femur (child) without displacement, and of one month's standing; the space between the fragments is well shown.

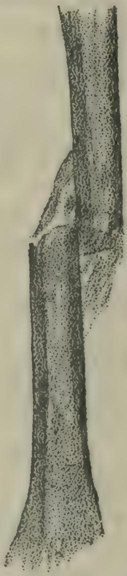


Fig. 2.—Callus produced from the periosteum which has been stripped in the direction of the displacement; fracture with complete transverse displacement but without overlapping of the fragments.

ness of the former bone—for a long time, if not for good; it is chiefly subperiosteal, and shortening is inevitable (fig. 4).

By angulation of fragments the direct transmission of pressure from one fractured surface to the other is still more interfered with. The principal rôle is played, both originally and ultimately, by the mass of sub-periosteal bone which grows in the area of the angle formed by the two fragments; the bone, when finally united, remains crooked, the seat of union is always considerably thickened, and shortening of the limb is inevitable (fig. 5).

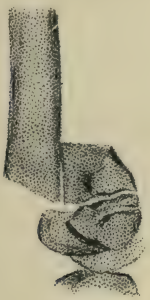


Fig. 3.

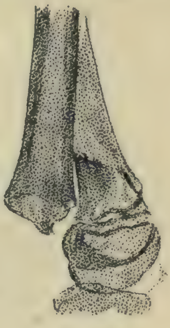


Fig. 4.

Fig. 3.—Fracture with transverse displacement and overlapping of fragments. The callus has been produced by the periosteum, which has been stripped from the shaft on one side only (fig. 4).

In these cases, despite the slight degree of calcification that the relative transparence of the callus indicates, union was sufficiently firm to allow of walking.

These two displacements are frequent, and it should be recognised that this fact has a direct bearing on the problems of treatment. It is certain, however, that they are often inevitable, the severity of the immediate infection and the extent and position of the wounds having made the proper application of splints difficult, both in the early and in the later stages of treatment.

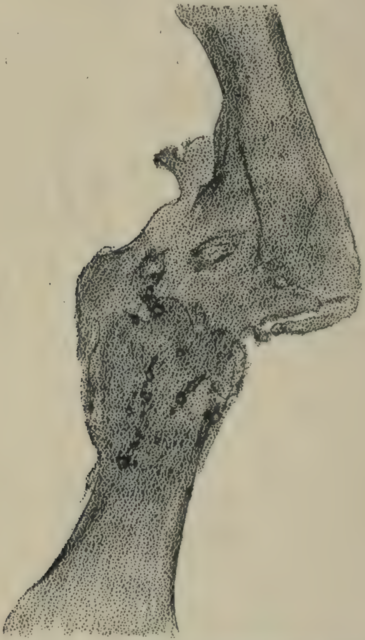


FIG. 5.—Union with marked displacement and angulation of the fragments of the femur.

The mechanical effect of angulation is twofold: not only is there diminution in the functional length of the limb, even in cases where the two fragments have not overlapped, but in addition such an interference with the normal range of movement of the joint below the fracture, as I will explain in detail further on (*vide* page 201).

In war surgery, especially in the case of the femur,

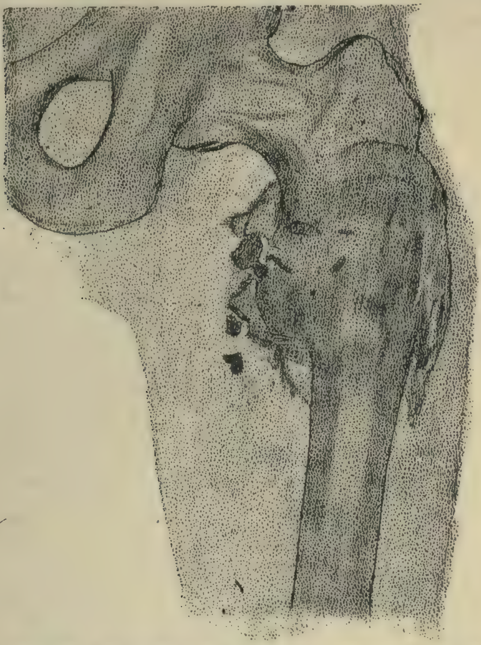


FIG. 6.—Fracture of the femur, with shortening due to neither angulation nor overlapping, but to actual loss of substance. The bullet has been broken up into fragments.

whatever care may have been expended in the mechanical treatment of the fracture, real shortening, not due to overlapping or angulation, occurs with peculiar frequency. We can do nothing, in fact, for the often considerable space left by a loss of bony substance (fig. 6). The consequences of such bone loss differ according as to whether there exists in the same segment of the limb an unfractured companion bone (as in the forearm and in the leg) or not (as in the thigh and in the arm). I shall deal first of all with such loss in the humerus and in the femur.

Let us suppose in one of these bones the loss of a whole segment of the shaft. Where the periosteal sheath has been sufficiently spared by the trauma and has retained its vitality, repair takes place by periosteal osteogenesis. But if the limb had been left to itself, the contraction of the long muscles would inevitably effect the elevation of the lower fragment into contact with the upper, so that a considerable shortening would result. Such a tendency we overcome by means of continuous extension, realising, however, that there exists a limit to such an action : it is on that account, in my opinion, wise to preserve whenever one can a longitudinal guide or support to the periosteal sheath by respecting at the primary operation all adherent fragments of bone, and by refusing to be in too great a hurry to remove sequestra ; as long as these latter are not completely free, new bone is laid down around them to an extent much greater than is usually believed.

In this connection we should note a difference between shortening of the humerus, which, provided that sound union obtains, is of but little functional significance, and shortening of the femur, which, when it exceeds 4 centimetres, constitutes a disability both in walking and in standing, and one that interferes with the equilibrium of the pelvis and spinal column. In these days it is not rare to meet with cases in which the shortening from angulation and overlapping amounts to 10–15 centimetres, or even more.

Where the fracture has soundly united, shortening of one of a pair of bones taking place in the lower part of the segment of a limb results in a deviation of the hand or the leg below the fracture towards the shortened bone. This is what occurs, for example, in the case of the fibula after a badly reduced Dupuytren's fracture, although this is the only case in which a fracture of the fibula has such an effect; in fractures through the middle of its shaft the tibia prevents displacement and acts as a splint; every one is familiar with the subluxation of the upper end of the radius or of the fibula that may follow a fracture, with shortening of the upper third of the ulna or of the tibia respectively.

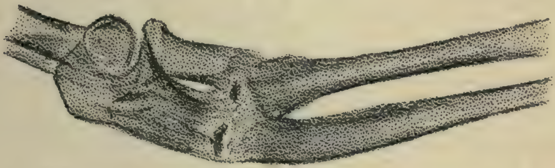


Fig. 7.—Fracture of both bones of the forearm united in pronation, and with synostosis of the radius and ulna and sequestra. Wounded 26th January 1915; date of radiogram, 17th February 1916.

Synostosis of two such neighbouring companion bones, although of no practical importance in the leg, results in the forearm in a serious disability that we have already studied (page 79).

When a loss of substance occurs of one of such a pair of bones, the other prevents the elevation of the lower fragment into contact with the upper; and although periosteal osteogenesis occasionally proves capable of bridging the gap, yet this remains one of the commonest causes of pseudo-arthrosis.

In the shortening of the lower limb due to actual loss of bony substance, whether of the femur or of the bones of the leg, our only resource is a surgical boot with a thickened sole; in connection with this I re-insist on what I have already said on page 68: that as far as possible the patient should be made to walk with the sole horizontal, despite the fact that the boot looks less inelegant if the heel alone be raised and walking takes place in equinus. Where the shortening, however, is less than 3–4 centimetres, correction may be limited to the addition to the heel only of a thickening that corresponds to half the amount of shortening.

Since the war there has come into use for cases of extensive shortening an arrangement that allows an independent thick cork sole to be fitted to any shoe; hence a remarkable economy, since with a single cork sole one can wear out several cheap shoes, surgical boots properly so called which require frequent repairing being always expensive.

In civil surgery a remarkable elongation of a limb shortened by overlapping of the fragments of a fractured femur can often be effected by an oblique osteotomy through the original line of the fracture followed by continuous extension. Even if the fracture had been complicated by infection—which is quite exceptional—the suppuration has almost always been but slight, union has taken place quickly and well; there is but little chance of any recrudescence of the infection. In war surgery I have already said that things are very different; operation should be considered only in cases where the shortening is considerable, and even in such cases most surgeons are inclined to abstain from intervention.

It has been proposed to remedy the mechanical disability of a short leg by resection—which should of course prove aseptic—of the opposite femur; this practice, however, does not seem to have attracted many supporters.

Shortening from angulation of the femur may likewise be improved by osteotomy. I have performed it but once in a case of truly enormous shortening (see page 76). Osteoclasis may be compared with osteotomy, but it has not been proved that recrudescence of microbic activity is any less frequent after the former than after the latter.

2. The Effect of Mal-united Fractures on the Action of Neighbouring Joints

I have thought that it would be useful to group together in this chapter certain rudimentary principles with which we are concerned in the study of the normal and pathological mechanics of the bones and joints.

Whenever, after the union of a fracture, the working of a neighbouring joint is interfered with and the range of its movement limited, it is usual to diagnose "ankylosis of the joint." When it is clearly established that the normal range of movement of the joint is definitely limited, such a diagnosis is of course quite correct. This does not, however, necessarily imply that the joint itself has lost anything of its potential former range; as a piece of mechanism it often remains in itself perfectly normal, nevertheless its physiological action has become abnormal; and in order to restore in such a case the previous range of function, the surgeon has to deal not directly with articular structures, but with a pathological condition that is completely extra-articular.

The rationale of such articular disabilities following fractures is really much less difficult to understand than "mathematico-phobes"—so numerous among medical men—seem to think; these disabilities are due to the displacement *en masse* in any direction of a joint that in itself remains perfectly normal. From this there necessarily results a displacement or change of its field of action which is increased in the direction of the articular displacement, diminished in the opposite direction; and the physiological problem before us is to ascertain in each case in what way such a change will affect the usefulness of the limb.

A joint may be regarded schematically as composed of a fixed rod (in the limbs always the upper bone or bones) with which articulates a lower movable lever. These, like all solid bodies, bear a definite relation to the three primary planes of space:

(1) The vertical transverse,
(2) The vertical antero-posterior, and
(3) The horizontal.

These are the geometrical terms which correspond to the anatomical:

(1) The frontal plane,
(2) The sagittal plane,
(3) The horizontal plane.

Since in anatomy the body is always regarded as vertical, the upper limbs hanging in complete supination and the long axis of the foot in the sagittal plane, we must regard this schematic joint that we are about to study as being similarly placed, *i.e.* with the axes of the two levers (the fixed and the movable) both in the sagittal plane, and the transverse axis of the joint between them horizontal. This, then, is the position of the axes of the schematic limb in repose, the movable lever lying in the position from which it starts its movements, whose range may be measured in degrees, and which we may call flexion and extension in the sagittal plane, adduction and abduction in the frontal plane, rotation in the horizontal plane around the long axis of the limb, which remains vertical.

Now when this joint is displaced in its relation to the rods by a kink or bend occurring in one or other or both of these its axis undergoes a change of plane. From such a displacement *en masse* of the joint itself, unaccompanied by any change in the articular elements or in the actual range of its potential movements, there results a change to new planes of movements of the rods themselves, and the practical question that arises is to determine accurately under what conditions these modifications of the action of the joint limit movement in useful directions, thereby diminishing the functional utility of the affected joint.

I will take as an example the simplest case, that of a hinge joint represented graphically by a transverse bolt at right angles to the two articulating rods, one mobile the other stationary. Using the arbitrary positions in space that we have adopted, we see that this joint possesses but the movements of flexion and extension. It is the type of the knee and elbow joints.

The most complicated form of joint, from the point of view of planes of movement—the ball-and-socket joint—possesses movements in every direction, including that of rotation. Of this form the hip joint is the type; we will study it later, especially in its relation to the movement of rotation and the analogous movements of pronation and supination.

A. The Effect of Mal-union on Hinge Joints

Suppose A B C to be a hinge joint, with C B fixed and movement of A B round B taking place forwards only. The point A turning round the point B describes the circumference of a semicircle, ending by becoming superimposed on the point C, having passed through 180°.

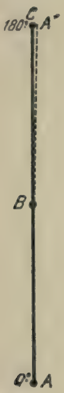


Fig. 8.

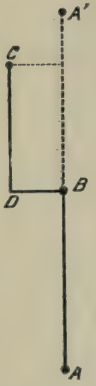


Fig. 9.

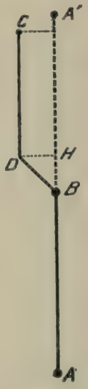


Fig. 10.

These two lines C B and A B determine a plane in which this movement of A B takes place. Let us regard this plane as coinciding with the sagittal plane of the body, and then see what takes place when the joint is displaced *en masse* by a kinking of B C. First in the frontal plane, second in the sagittal plane, and third in the horizontal plane. From the study of these the consequences may be readily deduced when the bending of B C takes place not in one but in simultaneous combinations of these three planes.

(*a*) *Transverse displacement of the joint* or displacement in the axis of the joint itself by angulation in the frontal plane of the fixed rod B C at the point D, forming either a right angle (fig. 9) or an obtuse angle (fig. 10).

Displaced thus, though unchanged in itself, the joint has lost its former axis with reference to the fixed rod C D. Its plane of movement will always be sagittal, but will now correspond to the line A B and no longer to the line C D. The super-position of A and C is now no longer possible; the point A will always be separated from C by a distance equal to that of D B. Hence we have displaced by this distance inward or outwards, to the right or to the left, the plane of movement of the joint, and whenever A B is flexed to 180° the point A will coincide with the point A′ along the prolongation of the line A B.

Where D B is oblique and not at right angles to C D, the amount of displacement of the plane of joint action will correspond to the projection D H (fig. 10).

The amount of this displacement is independent of the distance from the joint of the point D of bending, independent also of the length of the movable lever.

The range of movement—flexion—possible also remains unchanged, as the lever A B can still pass through 180° to take the position B A′.

In normal anatomy one sees this phenomenon exemplified, in relation to flexion and extension of the hip joint, in the angle that exists between femoral shaft and femoral neck.

Here the neck is doubly oblique, and the plane of the displacement correspondingly so, but the mechanical principle remains the same. The movements of flexion and extension of the shaft take place not in the sagittal plane of the femoral head, but in a sagittal plane some distance external to it : this does not at all affect the relative range of flexion and extension of this joint, but other things being equal and in accordance with a mechanism that I shall describe for sagittal displacements, it adds to the field of adduction at the expense of that of abduction.

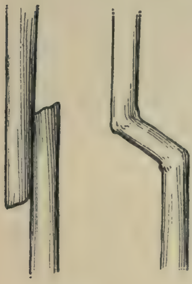


FIG. 11.

In the pathological condition of fractures a similar phenomenon occurs in those transverse displacements, in the extreme form of which the lower fragment slides up to lie along one or other side of the upper ; the longitudinal axis of this lower fragment is thus displaced sideways to the extent of its own thickness ; an analogous but rare state of affairs arises when in a double fracture the middle fragment lies more or less obliquely, so that the whole doubly bent lever becomes bayonet-shaped (fig. 11).

In such cases the amount of the displacement is small and of but little practical importance ; what is important in such cases is the shortening that has taken place.

(*b*) *Sagittal displacement of the joint, or displacement parallel to the axis of the joint.*—Let us refer again to our diagrammatic articulation, let us conceive the fixed limb as bent at D to an obtuse angle α, which lies on the side of the two levers opposite to that on which movement of the joint takes place, and the new axis B D as prolonged to B A downwards from the bend at D (fig. 12).

The joint B in itself has undergone no change, but in relation to the axis C D it has moved to the extent of the angle α.

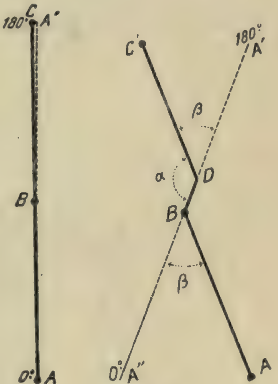


FIG. 12.

The position of A″, the new starting point of the movement (0°), is that where the rod A B lies in a straight line with B D; the end position of movement (180°) is that where B A′ is superimposed on the prolongation of B D, but this remains separated from D C by the angle β, the supplement of the angle of bending α. The range of movement remains unaltered in relation to the real axis B D, but in relation to the axis D C it has increased in one direction and towards one limit of the 180° of range, *i.e.* towards A″, and decreased to a corresponding amount at the other end, *i.e.* towards C′. Now if movement within the field represented by the angle A′ D C is functionally important, and in the field represented by the angle A B A″ of no practical use, the net result is a clear decrease of the range of usefulness of the joint.

This loss is directly proportionate to the distance which still separates the free extremities of the two articulating rods when movement towards each other has come to an end. Hence it is greater the nearer the bend or kink is to the point of articulation.

With the angle C D A′ equal in both, the triangles C D A′ are similar; hence the longer the side C D, the longer also in proportion will be the side C A′ (fig. 13).

This geometrical diagram may be applied exactly to our hinge joints, of which the best example is the elbow, when a transverse fracture of the lower extremity of the humerus unites at an angle with persistence of the backward tilting of the lower fragment.

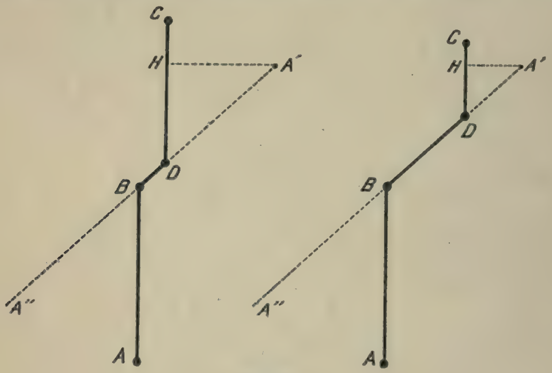


FIG. 13.

In the elbow, normal flexion has a range something short of 180°; it is limited by contact of the soft parts of the forearm and arm. Functionally, however, flexion should be regarded as complete only when the patient can scratch the front of the shoulder with the tips of his fingers; if the flexion falls short of this, we should diagnose a limitation of the full functional capacity of the joint, and technically the condition becomes one of ankylosis. The joint itself, however, remains quite intact and normal, but its movements, still of a potentially normal amplitude, have lost some of their functional usefulness, which exists only in relation to the long axis of the humerus; they are increased in the direction of hyper-extension of the joint, an increase of no functional significance whatever; they are decreased in the direction of flexion—a most prejudicial decrease from the functional point of view. In other words, flexion has been handicapped from the commencement, and by the time movement is complete it has not made up its handicap.

The typical case often met with is that in which, the joint remaining normal in itself, careful clinical examination establishes the existence of a negligible degree of hyper-extension. But if because of some additional articular lesion extension also is diminished, that does not of course alter the diminished flexion. The paradoxical condition may even occur in which, the forearm at the full limit of its extension lying in a line with the long axis of the arm, extension although practically normal is yet mechanically diminished (by articular lesion), whilst flexion mechanically normal (unaffected by such articular lesion) yet practically falls short of the normal.

The same thing happens in cases of Colles's fracture of the lower end of the radius, in which union has occurred with persistence of the backward tilting of the lower fragment, giving rise to the so-called "dinner-fork" deformity.

The normal movements of the hinge joint of the wrist take place in the two directions of flexion and extension in relation to the long axis of the forearm;

the point of commencement of both these two movements—the position of zero in the geometrical scale of these two movements—is the position in which the long axis of the hand lies in the direct prolongation of the long axis of the forearm. If, then, the lower fragment has united in a position of backward rotation round the transverse axis of the fracture, *i.e.* slopes backwards and downwards when the long axis of the hand lies in the line of this fragment of the radius, it will make with that of the forearm itself an obtuse angle open behind ; this constitutes an attitude of extension, the degree of extension being proportionate to the supplementary angle of this obtuse angle ; consequently, unless the wrist joint by an increase in its suppleness extends its normal range of movement, flexion will to a corresponding degree fall short of its normal.

In this fracture, the radius being shortened because of the impaction whilst the ulna retains its full length, it is the rule for the hand to become displaced outwards into abduction ; the range of abduction is thus increased, and that of adduction diminished ; but there is, in addition, a horizontal displacement due to an inclination of the normal axis of the joint. Such will be considered later.

We have described, as regards these displacements, their usual form in each fracture, that of backward tilting of the lower fragment towards the direction of extension of the joint.

Exceptionally in the case of the radius, very rarely in the case of the humerus, union occurs with the lower fragment tilted forwards in the direction of flexion ; in such cases the range of flexion is increased and that of extension diminished.

Such a state of affairs occurs in certain fractures of the lower third of the leg where union has taken place at an obtuse angle open forwards, the lower fragment sloping obliquely downwards and forwards. In such circumstances, with the foot at right angles to the leg and the knee straight it becomes impossible to plant the sole flat on the ground ; when the femur and upper fragment of tibia are vertical

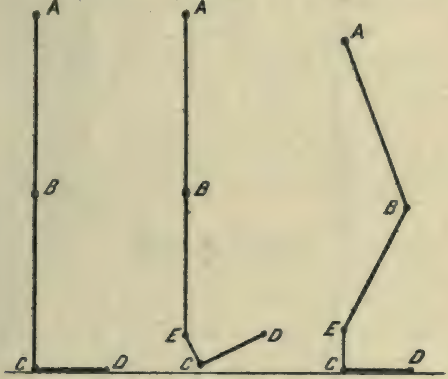


FIG. 14.

and the heel on the ground, as long as the ankle joint is held at a right angle it is quite impossible for the sole to come into contact with the ground, and the patient has inevitably to walk on the heel unless he resorts to one or two possible methods of compensation, either to flex the knee and then of course the hip (fig. 14), or else to drop the foot into a position of equinus, the latter method, however, limiting to a corresponding degree the natural rolling of the sole of the foot on the ground during walking.

Union in the opposite direction, the lower fragment obliquely sloping downwards and backwards, sometimes happens, in which case, when the foot is at right angles to the leg and the fore-part of the sole on the ground, the heel remains in the air and the foot in a position of equinus, although the range of flexion of the ankle joint still remains normal. Slight cases of this disability in the absence of any articular lesion gradually develop an increased range of flexion of the foot, which thus compensates for the limitation of flexion we have just described. In severe cases either the patient has to walk on the fore-part of the foot, which, unless compensated for by the existence of some shortening of the limb, is most inconvenient and awkward, or else he develops a progressive hyper-extension of the knee joint, which, if he persists in walking with the sole flat on the ground, in the end becomes a real compensatory genu recurvatum (fig. 15).

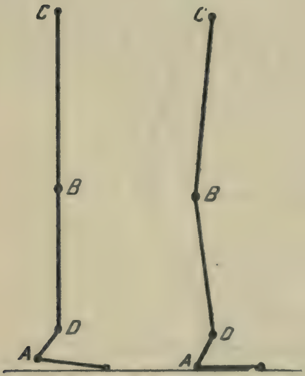


FIG. 15.

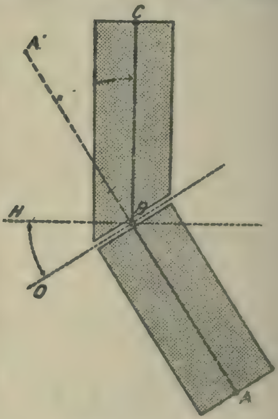


FIG. 16.

(*c*) *Horizontal displacement* by an abnormal inclination of the axis of the joint.

The joint A B C is viewed from the front and represented in its breadth so as to show the obliquity of the axis; the lever A B must always move at right angles to this axis, hence, this axis being oblique, it moves obliquely in relation to the bar B C. The plane of movement hence is no longer sagittal, and on flexion the point A comes to lie at the point A′ away from C on the side opposite to that to which the obliquity of the articular axis has displaced the free end A of the lever. The angle of deviation of the lever A′ B C is equal to the angle of deviation of the articular axis H B O. The absolute amplitude of the displacement (A′ C) depends on the length of the lever (fig. 16).

This case is not, then, an example of a simple angulation of the bone, but that of an elongation of one side of the fixed bone lever, the other side retaining its original length. Such a state of affairs occurs in supra-condylar fractures of the humerus united in varus; in such, flexion of the elbow joint, often of normal range, carries the hand well to the outer side of the shoulder, and the hand approaches the mouth only by a combination of abduction with internal rotation.

B. The Effects of the Mal-union of Fractures on Ball-and-socket Joints

The hip joint is an example of a ball-and-socket joint which not only allows of movement in all directions, but also permits, by an association or combination of these various movements following one another in rapid succession, the further complex movement of circumduction.

(*a*) By reason of the angle that exists between the femoral neck and the femoral shaft the hip joint is, so to speak, displaced inwards ; and since the neck of the femur slopes downwards, outwards, and slightly forwards, the effect of this displacement is correspondingly complex.

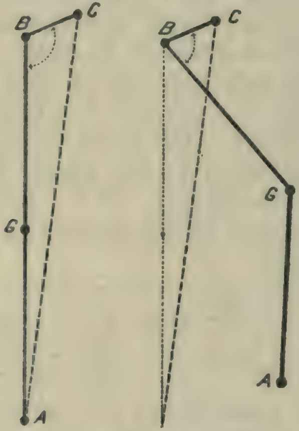


Fig. 17.

The mechanism of this joint may be easily understood if one considers the movement that takes place in each plane as the movement of a hinge joint. As these planes are, for flexion and extension the frontal plane, and for adduction and abduction the sagittal, one will readily comprehend that this natural displacement of the joint places a slight handicap on flexion—normally so important a movement of the joint—and a great handicap on adduction.

Any decrease, then, in the femoral angle at B will displace the shaft further into adduction, consequently will diminish the range of abduction. Every increase in this angle will have the converse effect (fig. 17).

(*b*) As regards rotation, let us commence by studying its effects in the case of a straight lever.

Suppose we erect a vertical axle rotating on pivots at its two ends, one of which rests on the ground. Regarding this as representing a human limb, and as standing in the sagittal plane, let us fix to each end of it half a crossbar, each of which also occupies this plane, so that the whole (leaving out of consideration for the moment the femoral angle) represents a lower limb, and the lower half crossbar, resting on the ground, the foot.

Suppose now we cut this axle across at any point between the level of its two crossbars and rotate the lower segment a slight distance round its vertical axis and then rejoin it to the upper in this new position; now, whenever the upper crossbar lies in the sagittal plane at the position of 0°, the lower will make with it an angle proportional to the amount of the rotation either inwards or outwards, and in whatever direction and to whatever extent the whole be now rotated, this constant angle between the readings of the degrees of rotation of the two crossbars will remain.

Such a condition as is here represented sometimes actually occurs in fractures of the femoral shaft that have united with but little or no overlapping, but in which some passive external rotation of the lower fragment has been allowed to persist uncorrected. If in such a case the amount of internal rotation possible at the hip joint still allows the long axis of the foot to occupy a plane a little internal to the sagittal, the functional disability that results is of little practical importance; even where the ability to rotate the leg and foot inwards is lost—in other words, where the long axis of the foot can just reach without passing the sagittal plane—the disability remains still practically negligible. In extreme cases, however, in which the long axis of the foot, with as full internal rotation at the hip joint as possible, fails to reach the sagittal plane, the functional result is one of grave disability. In the first case the displacement of the lower fragment, and hence of the leg and foot, into a position of external rotation is less than the normal amount of full internal rotation at the hip joint; in the second case these two—the external rotation at the seat of fracture and the full normal internal rotation at the hip joint—are equal; in the third case the latter is less than the former, and a mathematician would say that the amount of internal rotation was a negative quantity.

(*c*) So simple and uncomplicated a displacement as we have here used as an example occurs but rarely; the displacement is usually a much more complex one, and takes place in all three of the primary planes.

Other things being equal, the functional consequence of such a displacement in rotation does not vary with the height of the mal-union; on the other hand, the higher up the femoral shaft towards the hip joint union with angulation takes place, the more serious the limitation of the range of abduction and adduction, and such angulation is the more likely to occur the higher the seat of fracture. The extreme cases of such displacement with angulation are usually subtrochanteric fractures.

If such fractures be left to themselves and neglected, without considering for the moment the element of the deformity due to the overlapping of the fragments, the shaft will be found to unite at an angle in the following manner: the upper fragment becomes flexed and considerably abducted, and slightly rotated outwards; below it the lower fragment falls passively into a position of external rotation, and sometimes of adduction as well. That is to say, that on the occurrence of union the fragments will form a considerable angle, open inwards, and when the limb comes to hang vertically, parallel to its fellow, as long as the pelvis is kept symmetrical as regards the three planes of space and the upper fragment like that of the opposite side occupies the sagittal plane, the lower fragment of the femur (and consequently also the leg and foot) is in a fixed position of adduction and external rotation, and sometimes too in slight extension.

If the pelvis remained immobilised one can easily see that such a displacement would result in the limitation or total suppression of the range of abduction and of internal rotation. These movements should be regarded as non-existent when the axis of the limb in the case of abduction, the point of the foot in the case of internal rotation, fails to reach a vertical line passing through the head of the femur. Sometimes even such a mal-union affects the range of adduction, a disability which cannot be rectified except by compensatory tilting of the pelvis.

It is by a process of pelvic tilting, similar to that occurring in cases of ankylosis of the hip joint in malposition, that compensation for such limitation of the range of these movements is brought about, elevation of the corresponding side of the pelvis in the case of the adduction of the limb, rotation towards the sound side in the case of the external rotation. Hence will be readily understood the functional gravity of these cases in which not only is there absolute loss of abduction, but even negative abduction, *i.e.* persistence of adduction of the limb when abduction at the hip joint has reached its limit. Correction of such adduction can be brought about only by a tilting of the pelvis, a procedure that merely adds an apparent shortening to the real shortening already existing, and always considerable in such cases.

(*d*) Such are the mechanical consequences of malunion of fractures of the shaft of the femur, regarded from the point of view of the movements imparted to the lower limb from the hip joint. Let us now study those of fractures of the femoral neck, *i.e.* of the part of the femoral lever that lies proximal to its normally existing angle. I have already shown how the diminution of the femoral angle (a rare condition) affects the range of abduction and adduction.

In cases of extra-capsular fracture of the neck with impaction, another variety of displacement of the lower fragment occurs, that of rotation with change of relation between the axis of the great trochanter (and hence of the femoral shaft) and that of the femoral neck.

If one looks perpendicularly downwards on to the upper end of a normal femur there will be seen a bar of bone expanded at its two ends, one forming the femoral head, the other continuous with the femoral shaft; this is represented in the diagram (fig. 19) as a straight linear axis.

In extra-capsular fractures the neck becomes impacted into the posterior part of the great trochanter; the posterior surface of the neck thus becomes shorter than the anterior, so that the cervico-trochanteric axis becomes concave backwards, as represented in diagram 19—a curved axis.

Let us now consider the mechanical results of this change. The movement of rotation of the femoro-tibial lever does not take place round the longitudinal axis of this lever, but describes an inverted cone around the imaginary line passing from the head of the femur to the point of the heel; that is to say, that rotation on the heel corresponds to a movement of the neck around the head, the great trochanter describing in a horizontal plane the circumference of a circle of which the neck forms the radius; the position of commencement of the movement—the 0° of the scale of rotation—should be considered as lying a little in front of the frontal plane passing through the femoral head, since in the unrotated position—the long axis of the limb being in the sagittal plane—the neck slopes obliquely downwards, outwards, and forwards. During internal rotation of the limb the great trochanter moves inwards and forwards from this point, conversely during rotation outwards it passes outwards and backwards (fig. 18).

Let us now conceive the neck of the femur as bent to form an obtuse angle open backwards; this will, then, place the great trochanter behind the prolongation outwards of the femoral head. This means that when the articulating end of the lever is in a position midway between internal and external rotation—the 0° of the scale of rotation—its free lower extremity is displaced into external rotation. Hence in proportion to the amount of this displacement the range of external rotation is increased at the expense of that of internal rotation, which is thus diminished, suppressed altogether, or even becomes a negative quantity.

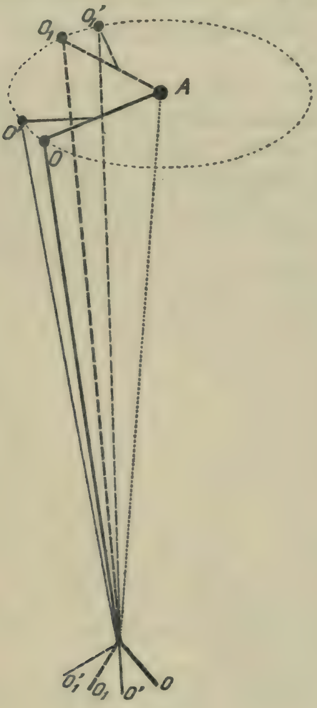


Fig. 18.

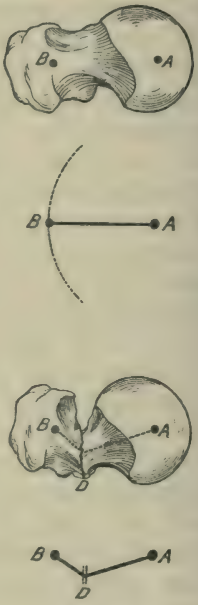


Fig. 19.

(*e*) *The effects of mal-united fractures of the humerus on the range of movements of the shoulder joint* are from the practical point of view of but little importance.

In connection with such cases of mal-union of humeral fractures, which of course are far from uncommon, it is obvious that:

(1) Union with acute angulation of the humeral shaft outwards (a frequent variety) and inwards will diminish respectively the ranges of abduction and of adduction.

(2) Union with acute angulation forwards and backwards will diminish respectively the ranges of flexion and extension.

(3) Union with rotation of the lower fragment in one direction around its longitudinal axis will diminish the range of rotation of the shoulder joint in the opposite direction.

All these disabilities, however, on account of the compensatory movements of the scapula that come into play, have but little functional significance, and are on the whole negligible.

If the scapula be fixed quite firmly and the humerus moved through its range of pure abduction in the frontal plane, this will be found to stop short before the arm reaches the horizontal; but when the movements of the scapula are no longer restricted, this bone tilts and so allows the humerus to reach—and even in young people to pass beyond—the vertical position. As there is normally no interference with this free range of movement of the scapula—the clavicle does not in the least restrict its power of increasing the range of movements of the shoulder joint—it will be readily understood that the loss of some degrees of abduction at the shoulder joint becomes hardly appreciable. The same applies with equal truth in the case of the movements of flexion and extension of the arm.

(*f*) *Mal-union of the radius and ulna resulting in limitation of the range of supination.*—Without entering into a full discussion of the details of the question—still a vexed question—of the movements of pronation and supination, we may say that the movement of pronation from the position of full supination consists of a rotation around its vertical axis of the upper end of the radius on the capitellar surface of the external humeral epicondyle, whilst at the same time the lower radial extremity describes a semicircle from without inwards round the ulna (which, however, also undergoes a movement of its own).

In cases of complete fracture of both bones the instinctive position assumed by the patient if left to himself is one of slight flexion of the elbow joint, with the palm of the hand resting either on the bed alongside the body (the hand being in complete pronation) or else on the abdomen (with the hand in semi-pronation). Now the upper fragments of the two bones remain fixed in supination, hence the movement of pronation has taken place at the site of fracture and not at the elbow joint. If, then, this is not attended to, union of the bones will take place in such a position, and the mechanical result will be diminution or suppression of the range of supination according as the lower fragments have been kept in a position of partial or full pronation compared to the full supination of the upper.

A similar result is liable to follow fractures of the radius alone, and in these conditions an accompanying non-union of the ulna would rather serve to lessen the functional disability. It would allow of freer movement of the lower end of the ulna, which could thus rotate, instead of the lower end of the radius, whose semicircular range has been either diminished or altogether suppressed.

It must be understood that we are dealing here only with the results of this particular form of mal-union—with fixed pronation of the lower fragment—and not with the other varieties of mal-union of the bones of the forearm, angulation, shortening of the radius, the blocking up of the interosseous space by excessive callus, or the occurrence of synostosis ; the practical conclusion to be drawn is that fractures of the forearm should be treated by immobilisation in supination, and not, as has been so often advised, in pronation or even in semi-pronation. In the gunshot fractures of the present war with extensive wounds and infective complications this is not always possible, but it is the goal at which we should aim.

Practical Conclusions

I have written this chapter, despite the dryness of its geometrical examples, because it seems to me to convey a lesson of great practical importance.

In the first place, I have endeavoured to show in the course of this chapter what care and attention we should devote to the correction of the displacements, active and passive, of the lower fragments of fractures ; pronation of the hand and wrist ; outward rotation of the leg ; backward displacement of the lower extremities of the humerus and tibia ; angulation in fractures of the femur.

And when we meet with a case in which such a mal-union has taken place, it is important that we should recognise its mechanical significance and not go on treating the limb by perfectly useless manipulation or mechanotherapy. Massage, mobilisation, heat, baths, electricity—all constitute the veriest waste of time both for the surgeon and, what is worse, for the patient. There is nothing wrong with the joint itself, and the muscles are impotent to overcome the disability.

Yet I have seen many such cases treated for long periods by these means, which are from the very nature of the lesion useless, and all for the lack of careful clinical examination and accurate interpretation of an X-ray plate.

According to the importance of the functional disability in these cases, either leave them alone or perform osteotomy: the only treatment of the least use is to correct the axis of the bony lever. As to the exact nature of the deformity and of the correction required, their recognition will depend, in each particular case, on a knowledge of the phenomena we have described in this chapter.

3. The Excessive Formation of Callus

An excessive amount of callus is due to two causes: (1) imperfect reduction with overlapping of fragments, (2) excessive sub-periosteal osteogenesis.

This second cause has a maximum effect when the periosteum is infected, or at least abnormally irritated, even if infection itself is not apparent—which does not mean, however, that it may not really be present.

We see examples of this phenomenon, whatever some may say about it, in a number of simple fractures treated by open operation, with sutures, clamps and plates of various shapes and sorts. When, some time after the operation, successive X-ray plates of such cases are carefully examined, it is evident that the volume of sub-periosteal callus is abnormally great, and that it often keeps growing, little by little, for several months. This callus again remains tender to pressure, and even really painful; it has a tendency to undergo rarefaction around the foreign body that is keeping up the irritation, and secondary elimination after late suppuration is not uncommon, whilst surgical removal undertaken to relieve pain and persistent inflammation is at times necessary.

If this is the case with foreign bodies of surgical origin, whose asepsis is not always absolutely beyond suspicion, although at first apparently sufficient, it will be readily understood that when, in war surgery, foreign bodies remain embedded in bone the effect is bad even if primary suppuration has been absent, or only slight and of short duration.

This is frequently the case in certain fractures in which the covering of the bullet has been torn, and in which the lead has broken up into small pieces on striking the bone. (See fig. 6. The large foreign body is the hard covering of a bullet.) In such cases the callus produced remains for a long time hot and painful, and is only slowly absorbed and remodelled, specially if irritated by massage or untimely mobilisation.

The same thing happens, with more certainty, in the case of foreign bodies which are clearly infected, and it is on this account that, in my opinion, the various osteosynthetic operations are but rarely indicated in the immediate treatment of gunshot fractures. For the most part these pieces of metal are badly tolerated, they keep sinuses open, cause necrosis, and—more often than is usually thought—result in non-union. I shall have to return to this subject later.

In general, excessive formation of callus occurs in infected fractures, especially in those in which sinuses remain open.

Even in cases which are not or are no longer fistulous, excessive callus is often the result of an infection, which is latent for the time being, but susceptible for an indefinite period of giving rise to a more or less acute exacerbation of inflammation—either spontaneously, or as the result of interference.

For the moment excessive callus concerns us inasmuch as it interferes with the function of neighbouring structures, which are displaced, compressed, or involved by it.

In the neighbourhood of a joint it limits the normal range of movement: we will discuss this in connection with ankylosis of joints.

Muscles, tendons, and vessels nearly always accommodate themselves fairly quickly and well to changes of relation and direction in this way imposed upon them. To liberate by operation adherent tendons seems to me to be but rarely indicated. On the other hand, the involvement of nerves which are enclosed, irritated, or stretched by callus is fairly frequent, and forms a clear indication for operation.

Excess of callus in such cases is usually but not invariably present; it does not, moreover, change the surgical indications at all, and only affects the technique of the operation to a slight extent. This consists in finding the nerve as near as possible to its point of entrance into the callus, but where it will certainly be free from it; with chisel and mallet the nerve is then followed through the bone, in which a groove is cut along its course.

To understand properly the connection of certain nerves and certain bones is merely a matter of anatomy —*e.g.* the circumflex nerve winding round the neck of the humerus (its involvement is rare), the external popliteal around the neck of the fibula (involvement infrequent), the musculo-spiral around the middle of the humerus (involvement frequent).

The incision by which the bone is approached—most often the humerus in cases of musculo-spiral involvement—is the same as that for suture of the nerve or for freeing it from scar tissue. The only difference in the operation is that in the present case an uninterrupted nerve trunk is found which requires no suturing, but which does require to be protected, just as if it had been sutured, against any renewal of compression or involvement, the best method being, in my opinion, to encircle it with a flap of muscle taken from the triceps in order to remove all direct contact between nerve and bone.

The practical differentiation of the two conditions, solution of continuity requiring suture and compression requiring liberation, is, however, a matter of the greatest importance for the surgeon.

If division of the nerve is diagnosed, suture has a chance of success only when healing by first intention (I mean of the operation wound, and not of the nerve itself) is assured. The operation will therefore only be carried out when the fracture is united, and when suppuration has ceased for several weeks; of course the operation must not be too long delayed, but, in order to ensure success, early operation is to be considered a matter of the second and not of the first order of importance. Whether the division of the nerve has lasted a second or a year, the processes of degeneration in the lower portion and subsequent regeneration from the upper remain the same. There are of course many obvious reasons for operation without unnecessary delay so as to avoid as far as possible certain secondary lesions in the muscles and joints, but the chief concern is that the sutured nerve does not suppurate. I do not insist further on this point, which will be treated in a special volume.

If, on the other hand, compression or irritation of the nerve is diagnosed, it is necessary to operate at once, for ascending neuritis commences and increases quickly, and the nerve fibres must not be allowed time to undergo further degeneration. Operation should be immediate even if the fracture is still septic, and even if it is not certain that definite sequestra have as yet been formed.

When removing sequestra or operating on a bony cavity, if a divided nerve is found, the correct course is certainly to suture it, for very often it can be isolated sufficiently from the seat of suppuration; but this will be only an accessory to the main operation, that is to say, an exploration of the nerve would not have been undertaken if it had not been necessary to operate upon the fracture. This applies also to early operations on suppurating compound fractures.

The diagnosis between anatomical division and compression by callus is in theory very easy. The paralysis is immediate, sudden, and complete in the former case; late, progressive, accompanied by neuralgic pains, often with retention, at least partial, of some forms of sensibility, in the latter.

In the case of a patient who soon after being wounded has come under the care of an observant surgeon in a hospital where there has been sufficient time and opportunity for a complete and thorough examination, this differentiation becomes subsequently a simple matter. But often at the base we receive wounded after several weeks or months, bearing labels on which the information is insufficient. This is inevitable on the evacuation labels from the field-dressing stations. In action there is no time to devote to detailed observations (which are, moreover, of little use), much less to write them on the label. It could, I believe, be avoided in the notes of a regular hospital. But I have had to regret, even from these, the frequent absence of any accurate notes. We are, then, often reduced to accepting the word of the patient, who has not always had the presence of mind to notice whether, at the time of the accident, a drop wrist or foot complicated the general uselessness of the limb, and once splints have been applied, has been no longer in a position to take notice of these points.

From time to time one is forced to remove a projection of bone that is threatening to ulcerate or has actually ulcerated through the skin.

4. False Joints. Loss of Bony Substance

(1) VARIETIES OF FALSE JOINTS

Before studying the treatment of false joints, it is necessary to distinguish with care the varieties of delay in union.

The average time necessary for the consolidation of a simple fracture in good position in a young and healthy adult varies, according to the size of the bone, from one month in the case of a bone of the forearm to two months in the case of the femur. This period is lengthened (1) when reduction has been imperfect and the periosteum almost alone contributes to the formation of the permanent callus, (2) when the fracture is comminuted. It is an especially long period in cases of compound suppurating comminuted fractures, and in war surgery we have often to count on a fracture of the femur with or without a sinus taking from four to five months to become firm. A period longer than this constitutes a definite delay in union.

In theory, the difference between delay in union and a false joint is clear. Whatever time has elapsed, delay in union is characterised by persistence of the osteogenetic process; a false joint by the final arrest of this process between the two fragments, each of which has undergone separate cicatrisation. In practice, the diagnosis between the two conditions is not always easy. The time that has elapsed, as I have just said, is not the criterion; a simple fracture with an interposition of muscle becomes, so to speak, immediately an example of a false joint. On the other hand, certain fractures ultimately unite without any special surgical treatment at the end of a year or an even longer period. This remark applies especially to cases where irritation of the seat of fracture is kept up, suppuration having ceased, by the existence of a foreign body in the bone, whether it be a projectile, wire, a metal suture peg, or plate of surgical origin. One must judge of the question by radiography.

When the fractured bone remains flexible, if there is still a persistent sinus we should always admit in principle that it is a case of delayed union, and, after radiographic verification, extract the sequestra and excavate the diseased area. Very numerous are the cases in which, after several months of suppuration, clearing out the infected area of the bone, specially if there have been sequestra, leads to a rapid return of the process of ossification, which previously had come to an almost complete standstill. In operating for chronic osteomyelitis I have several times noticed that in the middle of the sub-periosteal hyperostosis the fragments of the diaphysis were united only by dense fibrous tissue, which later has undergone ossification.

Palpation of the site of fracture supplemented by radiographic examination enables us to form a fairly correct clinical conclusion.

The principal characteristics of a real false joint are considerable abnormal flexibility, absence of pain on movement and pressure, and absence of tension and œdema in the soft parts that are more or less adherent to the seat of fracture. If the bone ends are still enlarged and the soft parts infiltrated with œdema, if the bones are only a short distance apart and the amount of abnormal mobility slight, if movement causes pain and even light pressure is painful, then one may safely conclude that there is merely delay in union, in which there is no indication for a hasty operation.

In these cases radiography gives useful information, but one must be able to appreciate the exact significance of the various details. In the first place, it should be remembered that callus, especially intermediate callus, often casts no shadow on an X-ray plate for a considerable time, even though clinically the union of the bone seems complete (see fig. 1); again, it is often impossible to diagnose by examination of the negative cases in which the callus is still but poorly ossified; and when on manual examination we no longer find abnormal flexibility or tenderness, that does not mean that in the lower limb we may not be surprised by late angulation from bending of the callus under the body weight. The common fracture of Dupuytren long ago taught us the necessity of forbidding early weight-bearing when we suspect but slow ossification of callus.

When all suppuration has ceased and abnormal mobility still remains, radiography permits us to establish one of two points: the presence of a considerable bony loss, the end of the fragments being far apart, or else the presence around the seat of fracture of a greyish shadow with indefinite edges, a sign of very slow calcification of callus. In this latter case the value of successive radiographs at monthly intervals in order to follow by the increasing opacity of the shadow the progress of ossification will at once be obvious; even where there is considerable loss of substance of the shaft, regeneration of bone from the sheath of surrounding periosteum is not at all exceptional if one only has the patience to wait for it.

In the typical plate of a true false joint the shadow of the fragments should appear opaque and of a regular or irregular shape, but with very clearly marked definite margins like that of the bone of a completely healed amputation stump.

In war surgery the usual cause of a false joint in the shaft of a bone is this loss of too great an extent of bony substance, the result depending on whether there exists but one bone in the limb segment (arm and thigh) or two bones (forearm and leg). In the former case, elevation of the lower fragment often allows consolidation to take place at the expense of considerable shortening. In my experience, pseudoarthrosis in the shaft of the femur is rare; in the humerus, it is rather more common.

Where there are two companion bones in the limb segment, if one has escaped fracture, or if fractured has united without or with but little shortening, it places a very definite obstacle in the way of approximation and union of the two fractured ends of the second bone. This condition of affairs occurs sometimes in the leg, more often in the forearm. Pseudoarthrosis occurring simultaneously in both of the bones of these segments is very rare.

A special form, " articular " false joint, occurs when the loss of substance involves an epiphysis in the neighbourhood of a joint as well as the neighbouring part of the shaft, and when the wound has healed without ankylosis of the joint, which becomes flail.

Occasionally this occurs at the knee joint after an extremely extensive resection for very severe bone involvement or when a partial instead of a complete resection has been performed. This form of false joint, moreover, sometimes follows a resection of the hip, which has succeeded in saving the life of the wounded man, but which has resulted in a limb of but moderate utility, although infinitely superior to an artificial limb fitted to the pelvis after a disarticulation at the hip joint.

The usual position, however, for an articular false joint is in the upper limb, sometimes at the wrist joint from loss of the lower end of the radius, more often at the elbow and shoulder from loss of the corresponding epiphyses of the humerus.

The regular pathological type of false joint is that of fibrous union, the tapering bone ends being joined together by bands of fibrous tissue; either close fibrous union, rather rare, when the bone surfaces remain in contact, and when, if there is no interposed muscle, a late, slow ossification may for a long time be hoped for; or flail fibrous union, more common, when a considerable length of fibrous tissue replaces the lost bone. I have not seen cases of real "false joint," that exceptional form with fibrous ligaments and synovial lining.

(2) TREATMENT OF NON-UNION

It is necessary carefully to distinguish between the treatment of mere delayed union and that of true pseudo-arthrosis.

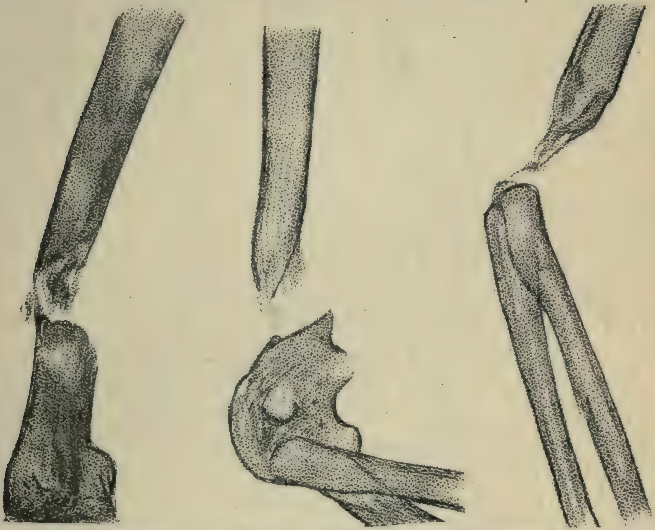
A. *Delayed Union*

I have already explained the rôle played in this by sequestra and foreign bodies, and the necessity for their removal.

In cases where neither of these two causes of delayed union exists, where suppuration has ceased, and there is no foreign body, and where on the removal of splints after the usual period abnormal mobility is found to exist, the difficult problem arises whether to persist in immobilisation or to leave the limb more or less unrestricted in its movements.

There are of course cases of delayed union—often wrongly described as false joints—in which, after a delay of some months, new bone formation has been stimulated by some purposive form of irritation of the seat of fracture—*e.g.* the old methods of treatment, forcible rubbing together of the fractured end, injection of mild chemical irritants, and acupuncture.

These various procedures are probably no more efficacious than permitting slight movement at the seat of fracture, the limb being either left free of all apparatus and lightly massaged, or else put up so that the movements of the neighbouring joints which are left unrestrained by apparatus cause a certain restricted amount of movement at the seat of fracture itself. A little movement is allowed, but only a little.



FIGS. 20–22.—Three examples of pseudo-arthrosis of the humerus; occurring in the middle of the shaft (fig. 20), in the lower part of the shaft with ankylosis of the elbow joint (fig. 21), the articular variety (fig. 22). In the last probably also the olecranon of the ulna has been resected. All three resulted in flail limbs, and in all were present sinuses which soon healed after the removal of small sequestra (fig. 20), or after excavation of a focus of caries (fig. 22).

As a general rule, this latter procedure seems to be preferable either to absolute immobilisation or to leaving the limb quite free. We should try it for successive periods of three to four weeks, noting at each change of apparatus whether the mobility appears less, and whether radiographs show an increase of ossification in the callus.

For this purpose the extension apparatus of Delbet for the humerus and femur, and his plaster splints, which allow the patient full use of the limb in fractures of the tibia and fibula, are most excellent. I am accustomed to apply these as soon as the pathological state of the parts allows of it, and to continue them as long as one is certain that a false joint does not exist.

If the delay in union is prolonged, particularly in the lower limb, and above all in the leg, it is easy to substitute for these heavy splints orthopædic apparatus similar to that prescribed for inoperable false joints, or for those in which operation has failed. This method of treatment avoids two very common practices which are to be condemned, viz. in the case of the upper limb, keeping the arm in a sling; in the case of the lower, giving the patient a pair of crutches.

Patient and careful observation is necessary before finally concluding that the process of consolidation has definitely come to an end.

B. *False Joints*

The means of treatment at our disposal are:

1. An open operation with the object of obtaining bony union.
2. The wearing of an orthopædic apparatus.

The principles of the orthopædic apparatus vary with the different segments of the two limbs; those of surgical operations are, however, general and constant.

(*a*) *If the fragments are in contact without loss of substance*, the old method of freshening the bone ends should first be tried. The seat of fracture is opened up, the periosteum preserved with the greatest care, intermediate fibrous tissue excised, and the ends of the bone freshened either with the curette or the saw, with the object of obtaining close contact between healthy, well-vascularised bony surfaces. By doing this there necessarily results a certain amount of shortening, usually of no importance in the case of the humerus, and even of the femur—where, however, pseudo-arthrosis rarely occurs—but incompatible with accurate coaptation of the cut surfaces in those segments of the limbs where there are two bones and the other is sound. If the separation of the surfaces is not great, this difficulty may be overcome by resecting a short segment of the normal bone; if the separation is considerable, we must have recourse to a bone graft.

After freshening the ends most surgeons assure the maintenance of the freshened surface in good and close apposition either by suture of the bones or by one of the methods by which this has been replaced and simplified in recent years (metal plates or staples), or else by an intramedullary peg of ivory.

I believe that there is a tendency to abuse the insertion of these foreign bodies in bone. Even when the seat of the fracture has throughout been closed and aseptic they irritate the bone, cause rarefaction, and provoke the formation of callus, which is exuberant but at the same time insecure. Secondary sinuses are far from being exceptional. Moreover, it is often possible without these to maintain good position by means of well-fitting external splints; but when this latter course is impossible, it is, in my opinion, better deliberately to remove the foreign body as soon as the callus has commenced ossification. Consequently I prefer fixation with wire, or, better still, with a staple, to the use of intramedullary pegs.

(*b*) *If there is such loss of bone* (either originally or as a result of removal by operation) as is incompatible with coaptation of the fragments, we must have recourse to bone grafting.

Sometimes it is possible to insert into the gap a bony fragment with an adherent pedicle taken either from the bone itself or from a neighbouring bone. I shall describe this in connection with losses of substance of the tibia repaired from the fibula (see p. 246).

Most often a separate fragment is taken from a distance:

Either from the patient himself, *autoplastic graft*;

From an animal of the same species, *homoplastic graft*;

From an animal of a different species, *heteroplastic graft*.

It is generally recognised that success is more likely if the graft retains its own periosteal layer, but this is not indispensable.

In the case of a pseudo-arthrosis a graft of large size must be used, and most often an attempt is made to introduce its two ends into the medullary cavity of the existing fragments.

From the study of experimental grafts in animals, and from their use in man in an aseptic field of operation, it has been found necessary to discriminate between two things, the "taking" of the graft and its ultimate fate.

I shall not consider cases where suppuration occurs and the graft comes away; the first condition of success is primary union of the operation wound. Further, it must be understood that antiseptics must not be used; they adversely affect the vitality of the cells.

In an aseptic case the graft usually "takes," even when it has been heteroplastic. In man, radiography has shown the bony fragment surrounded by callus; in animals, its survival and vascularisation have been established by post-mortem examination. The frequency of this immediate success should not, however, be exaggerated. More often than could be wished it is only partial: the fragment survives, but remains free at one end, sometimes even at both ends, and consequently consolidation is not obtained.

Even in cases that for weeks keep up a promise of ultimate success, one is liable finally to fail owing to a late but progressive absorption of the graft.

The present consensus of opinion is that even with an autoplastic graft this absorption is constant, or almost constant. The graft plays its part merely by exciting and directing an osteogenesis by substitution. This is a source of discussion of great scientific interest, but of no verygreat practical importance. If secondary ossification of the graft has occurred, it matters little whether the ultimate callus is formed by the transplanted bone itself or by new bone which has gradually replaced it, so long as in the end the continuity of the bony lever is re-established.

But if absorption takes place quickly substitution has not time to occur, and the final result is failure. Occurring in all three varieties of grafts, this excessively rapid absorption occurs in an increasing order of frequency with autoplastic, homoplastic, and heteroplastic grafts. Further, it may be said that the heteroplastic graft, the taking of which is more dependent on chance, and the absorption of which is more frequent, has not up to the present progressed beyond the experimental stage, despite a few fortunate successes, of which there are even some in classical surgery. This is a pity, because they constitute the most convenient method of obtaining at any time a massive graft.

An opportunity for the use of homoplastic grafts but rarely presents itself, and even when it does there is always the fear, despite all clinical and laboratory precautions, of inoculating the recipient of the graft with tuberculosis or syphilis.

Grafting by the autoplastic method alone is therefore carried out with any frequence, and the transplanted pieces are almost always taken either from the fibula (the whole middle third of the shaft of which can be resected without leaving functional disability), or from the tibia, whence a sufficiently long piece can be taken without difficulty from the crest.

Indications.—What I have said as to the absolute necessity for primary union after bone grafting, and its almost equal necessity after simple freshening operations with or without bone fixation, indicates that in war surgery the frequent recrudescence after open operations of infection, over which we have no control, forms a great stumbling-block in the way of success. It is advisable, therefore, to wait a very considerable time before operating; all vascularity should have disappeared from the scar, and the neighbouring tissues should be quite supple, and even then there is no absolute assurance of success.

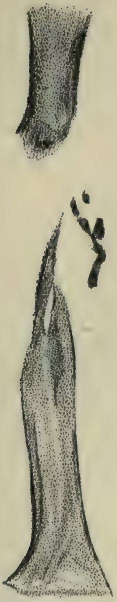


FIG. 23.

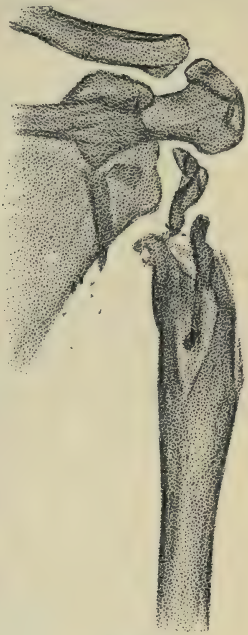


FIG. 24.

Even if the wound does not suppurate, failure to secure union is not at all rare.

In spite, then, of the incontestable progress of the last thirty years, the treatment of "false joints" by open operation remains uncertain. This is, however, no reason for refusing to consider operation as formally indicated if the functional disability is serious—as is usually the case—even if in case of failure one has to fall back on an orthopædic apparatus: nothing is risked, and the gain may be considerable.

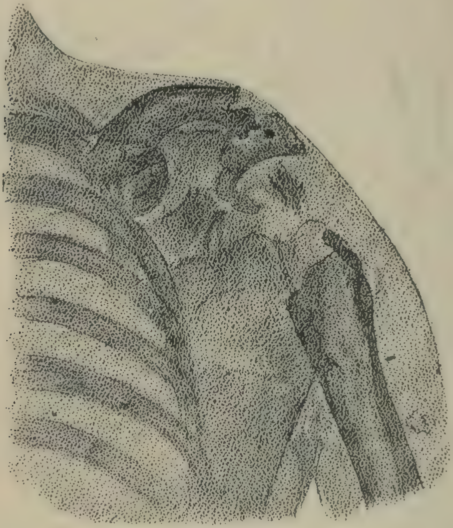


FIG. 25.

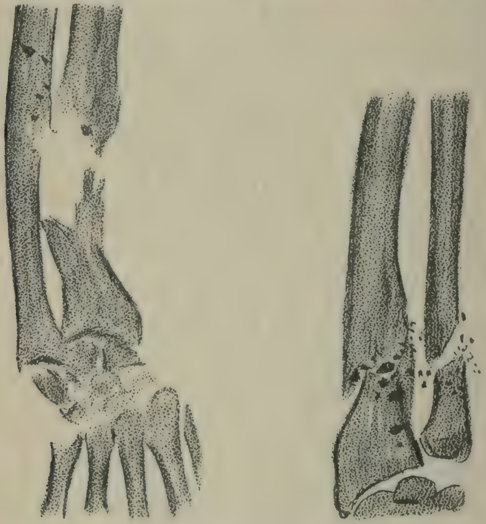
FIGS. 23–25.—Flail pseudo-arthroses of the humerus, involving the shaft (fig. 23) and the upper articular extremity (figs. 24 and 25). In cases 23 and 24 there are present sequestra whose removal was followed by rapid healing. In case 25 a sinus was due to disease in the fractured scapula.

I will now enumerate bone by bone the chief functional troubles which constitute indications for treatment.

In the case of the humerus, whether it be in the shaft itself, at the shoulder, or at the elbow, the type is that of a loose pseudo-arthrosis. This does not mean that the limb is useless. In extension the arm hangs beside the body limp and swinging like a pendulum. But if the muscles are good—particularly the deltoid for the shoulder and the long muscles for the arm and elbow—the effect of their contraction is to raise the lower fragment, and then by supporting it against the upper, with, sometimes, a remarkable security, to allow of fairly vigorous action of the wrist and hand, the elbow remaining flexed. In the case of a false joint in the shaft the lower fragment is held by the triceps so as to make with the upper fragment an obtuse angle open backwards; in this position the biceps can quite adequately flex the elbow and hold it flexed. By the use of a circular armlet which leaves the elbow free, the functional utility of such a limb can be considerably increased. In order not to constrict the limb and interfere with muscular action it is best for this armlet to have a proximal attachment to a shoulder piece which is fastened round the trunk.

In pseudo-arthrosis of the humerus cure by open operation is most difficult to effect. When the head of the humerus has been resected with the upper part of the shaft a vigorous deltoid can raise the lower fragment directly and keep it in contact with the glenoid cavity. But in all the cases of this sort that I have seen in war surgery there has been complete atrophy of the deltoid, and if ankylosis had been effected the functional result would have been better. Hence in cases of this sort original resection of the upper end of the humerus should be performed only when, in order to save life, the choice lies between this resection and disarticulation at the shoulder joint. Conservative measures which would result in ankylosis should be abandoned only after a full realisation of these facts of the case.

In the case of the elbow adequate voluntary movement at the site of the false joint is not rare; indeed some surgeons consider the functional result better than that of ankylosis of the elbow in good position—the muscles of the forearm and hand being equally good—therefore they prefer to treat by free and early resection fractures of the lower end of the humerus, of the upper ends of the forearm bones, or of the ends of all three bones. I speak here of immediate or early secondary and not of late orthopædic resection, which, being sub-periosteal, allows of the reconstitution and



FIGS. 26 and 27.—Pseudo-arthrosis in the lower half of the radius (fig. 26) and of the ulna (fig. 27), in the latter bone with but little loss of substance.

remodelling of a firmly ankylosed joint. When the fixation by the long muscles is insufficient—when the muscles are poor, or else the loss of bone too great—the elbow should be fixed in an apparatus fitted with a ratchet, which encircles the arm and forearm, and is suspended from the shoulder in the manner already described to avoid compression of the muscles.

In connection with these fractured shoulders and elbows I draw attention to the attempts that have been made to insert under the soft parts artificial joints of ivory fixed to the neighbouring bones. I mention these solely to show that I am not ignorant of them.

Pseudo-arthrosis, even if fairly firm, of the two bones of the forearm results in a grave disability, which is sometimes complete. That of the radius alone is almost as disabling because of the loss or limitation of the movements of pronation and supination, and because of weakness of the fingers, the hand being flexed in a bad position; when the lower radial epiphysis has disappeared the hand deviates to the outer side, supination is impossible, and weakness of grip of the fingers is very marked. Pseudo-arthrosis of the ulna is much less disabling, especially when it occurs in the lower half. It may even be a good thing, especially when the radius is badly united, the lower fragments being pronated, causing sometimes less complete limitation of supination.

The forearm is the region where fibrosis and destruction of muscles and tendons and nerve lesions most frequently complicate non-union of bone and increase considerably the functional disability of hand and fingers.

If an operation by freshening the ends with shortening of the second bone (if it be intact) or by bone grafting fails, a fair result is obtained by the use of a leather armlet in pseudo-arthrosis of the shaft. Neither operation nor orthopædic apparatus is, however, of much use in loss of the lower extremity of the radius.

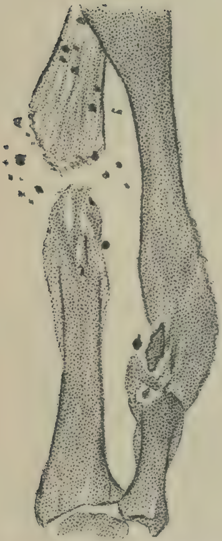


Fig. 28.—Pseudo-arthrosis in the middle of the shaft of the radius, with considerable loss of substance. Cavity containing sequestra in the ulna.

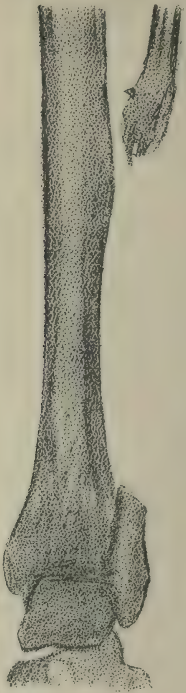


Fig. 29.—Loss of substance of the fibula without the occurrence of displacement of the foot (the external malleolus has escaped; ankylosis of the ankle joint).

In the *femur* I have as yet seen no case of non-union of the shaft among the many wounded that I have examined. I believe that simple freshening without grafting would be sufficient. In case of failure, one would apply an apparatus transmitting the weight from the tuber ischii to the foot, like the caliper used in the convalescent stage of hip disease. The same also is useful in the case of a flail hip joint after resection ; after this operation, however, ankylosis is much more commonly met with.

A flail knee joint, as I have already said, is rare ; a permanent support becomes necessary for it.

In the leg, pseudo-arthrosis without being frequent is not rare. The most striking characteristic is the lack of stability in the limb in the standing position, hence there is a very considerable difference between pseudo-arthrosis of the tibia and of the fibula. A loss of substance of the fibula—even when considerable—is almost always without functional importance, provided that the external malleolus and its attachments are preserved ; but if this is lost, deviation of the foot into valgus as soon as it touches the ground constitutes a very serious disability. The operative indication is then to arthrodese the ankle joint at a right angle, as is done for congenital absence of the fibula. I have seen a case of considerable loss of substance, but with preservation of the malleolus and stiffness of the ankle joint—which had been kept in a good position by the surgeon—walk very well and firmly, the sole of the foot flat on the ground (fig. 29).

Pseudo-arthrosis of the tibia without loss of substance, or with but slight loss—2–3 cm.—may often be treated successfully by freshening combined with shortening of the fibula, or else by a bone grafting, by freshening of the two bones if the fibula also has not united. In cases of failure a walking apparatus, with support from the tuberosities of the tibia attached to the thigh, like but very much lighter than an apparatus for amputation of the leg, almost always gives a fair amount of functional use.

The most difficult cases are those in which there is such excessive loss of substance of the tibia as renders impossible any attempt to procure contact between the two ends even after resection of the fibula. By means of a bone graft it is also impossible to reconstruct the tibia sufficiently in length and in thickness. In such conditions, sometimes callus forms spontaneously in a favourable manner, one or both ends of the tibia becoming united to the fibula, which has itself been broken but has joined, so that the fibula itself transmits the body weight; this bone is reinforced by callus—it seems to develop later little by little, and adapt itself to its new function, and the final result is often satisfactory. It is possible in some cases to imitate this natural process by surgical methods (figs. 30 to 33). Sometimes the shaft of the fibula has been implanted into the upper end of the tibia; sometimes, on the contrary, into the lower end of the tibia; sometimes, by two operations, both ends of the fibula have been implanted in turn, so as to substitute one entire shaft for the other (figs. 35 and 36). In this last case, although the absence of the middle part of the shaft of the fibula usually results in no disability, it is well to guard against the occurrence of a valgus deformity of the foot by creating a synostosis between the lower ends of the tibia and fibula.

It is more in accordance with the normal mechanics

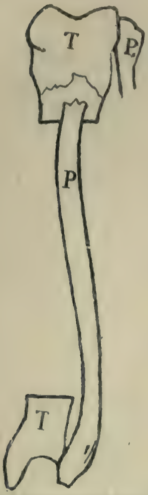
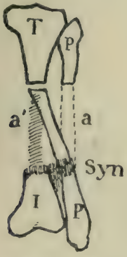


FIG. 30.—Simple transplantation of the upper end of the fibula into the upper fragment of the tibia.



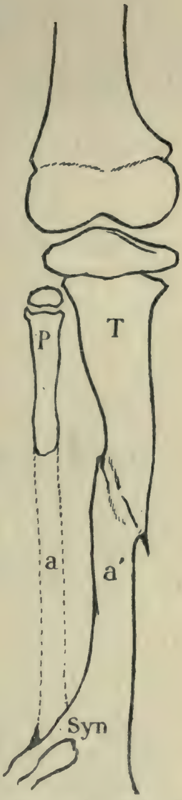


FIG. 31.—At the time of the operation.

FIG. 32.—The final result.

FIGS. 31 and 32.—After grafting of the upper end of the fibula into the upper end of the tibia, and after the performance of arthrodesis of the inferior tibio-fibula articulation, the fibular shaft *a* replaces the tibial shaft *a′*.

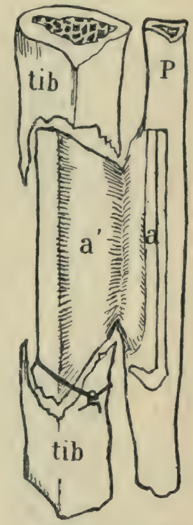


FIG. 33.—The operation of Curtillet—a fibular flap *a* is transplanted into *a′*, the gap in the tibia due to loss of bone.

of the leg, however, if, following Curtillet, the transplant is taken not from the whole of the fibula but only from the anterior half of its thickness. This osteoplastic strip, nourished by an internal pedicle formed of musculo-periosteal insertions carefully left untouched, is passed through an opening made into the antero-external muscles of the leg, and is placed between the two ends of the tibia, freshened and shaped like a fork (fig. 33).

After these various operations it has been frequently proved that the graft, studied by a series of radiographic plates, has rapidly grown and become an excellent tibial shaft.

Thanks to these methods, operative and instrumental, we may say that amputation is no longer indicated at the present time so far as the upper limb is concerned, and hardly ever in the case of the lower limb. It is possible, however, that in certain cases of flail pseudo-arthrosis of the leg this mutilation may be advisable—as in certain congenital false joints—if we consider that the apparatus will be more simple, and the support more secure with one of the excellent artificial limbs that can be made to-day for amputations in the lower part of the leg.

C. Cases of Non-union with an Unhealed Wound

Under these circumstances it is impossible in any individual case to be certain that union will not eventually take place; I have already pointed out how quite often after a clearing out of sequestra and patches of diseased bone further osteogenesis results in the attainment of late union. Where the destruction of bone has been extensive, however, the case will most probably end in the occurrence of a pseudo-arthrosis. In such cases very interesting results have been obtained by an extensive freshening followed by plating of the fragments, and this in the presence of sepsis; the wound is left open and the plate removed some few weeks later. The irritation induced by the septic plate seems, at any rate at first, to be favourable to the sub-periosteal production of new bone. In many cases this procedure will mean a considerable shortening of the bone, so that it is really applicable only in threatening pseudo-arthrosis of the femur and of the humerus. As regards the femur—non-union of which is, moreover, very rare—I have seen no published record of its adoption; in the case of the humerus, however, Tixier obtained a good proportion of successful results, of which he gave an account some months ago at the Société de Chirurgie. I have had occasion to remove both from the humerus and from the bones of the forearm plates of the Lane and the Lambotte patterns that were the cause of persistence of certain sinuses; these had, in my opinion, been left in far too long; nevertheless, I am certain that they played an essential part in the attainment of union in these cases.

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